DOCUMENT RESUME

ED 347 306 CE 061 515

AUTHOR Gallo, Dennis; And Others
TITLE Transportation Technology Curriculum Materials FY 90. Illinois Plan for Industrial Technology Education.
INSTITUTION Illinois State Univ., Normal.
SPONS AGENCY Illinois State Board of Education, Springfield. Dept. of Adult, Vocational and Technical Education.
PUB DATE Nov 89
NOTE 148p.; For related documents, see CE 061 514-518.
PUB TYPE Guides - Classroom Use - Teaching Guides (For Teacher) (052)

EDRS PRICE MF01/PC06 Plus Postage.
DESCRIPTORS Air Transportation; *Behavioral Objectives; Grade 9; Grade 10; High Schools; *Learning Activities; Rail Transportation; Technology; *Transportation
IDENTIFIERS *Illinois; *Technology Education

ABSTRACT

This packet contains technology-based learning activities for the transportation technology course at the orientation level (grades 9 and 10) of the Illinois Plan for Industrial Technology Education curriculum project. The packet includes a course rationale, mission, description, and course outline. Suggested learning objectives and suggested learning experiences for the following transportation areas are provided: introduction to transportation technology, land transportation systems, materials handling systems, water transportation systems, air transportation systems, and space transportation systems. The packet also contains over 20 student learning activities; representative topics are: automated guided vehicles, rotary-winged aircraft, programming robots, wind tunnel testing, rocket stability testing, calculating drag coefficiency, and testing air-foil designs. Numerous scale drawings and other figures are used to illustrate activities. (YLB)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED347306

Illinois Plan for Industrial Technology Education

Transportation Technology Curriculum Materials FY 90

Illinois
State Board of
Education

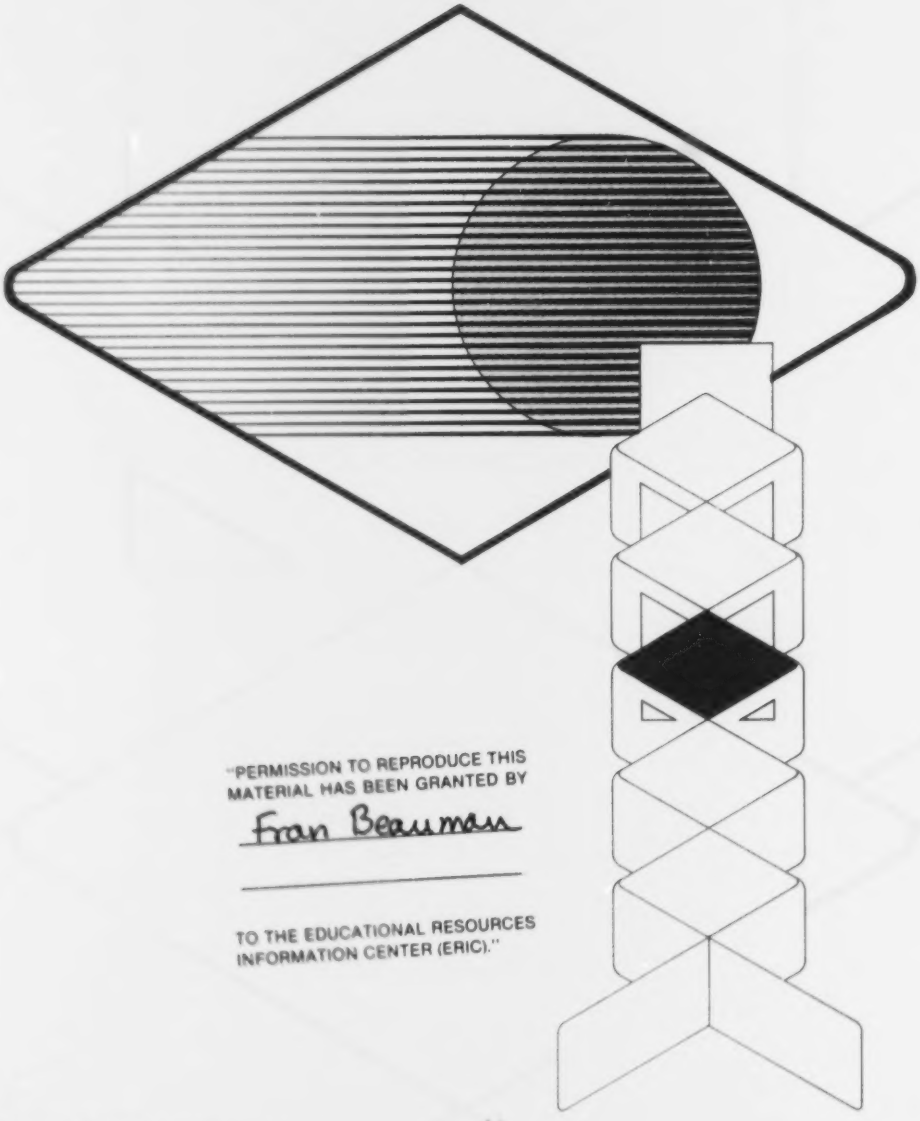
Department of
Adult, Vocational
and Technical
Education

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

This document has been reproduced as received from the person or organization originating it.

Minor changes have been made to improve reproduction quality.

Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.



"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

Fran Beaumaster

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

CE061515

BEST COPY AVAILABLE

Illinois Plan for Industrial Technology Education

Transportation Technology Curriculum Materials FY 90

Project Staff:

Director:
Franzie Loepp

Developer:
Dennis Gallo

Contributors:
Rick Bunton
Roger Fieser
Bob Freeman
Al Kane
Steve Reed
John Schira
Richard Vedder
Kenneth Welty
Ron Weseloh

Electronic Imaging:
Kathleen Hatch

Department of
Industrial
Technology

Illinois State University

Illinois
State Board of
Education

Thomas Lay Burroughs
Chairman

Robert Leininger
State Superintendent
of Education

Department of
Adult, Vocational
and Technical
Education

Vocational
Program Improvement
Section

November, 1989

PKAC22D

An Equal Opportunity/Affirmative Action Employer

TABLE OF CONTENTS

How to Use the Packet ii
Rationale, Course Mission iii
Course Description, Course Outline, Content Outline iv
Adapting to Nine or Eighteen Week Formats v

Introduction to Transportation Technology 1-I
- Transportation Problem Solving 3-I
- Propulsion 5-I

Land Transportation Systems 1-L
- Controlling Transportation Vehicles - Radio-Controlled Vehicle 4-L
- Two-Speed Torque Racer 7-L
- Designing Safe Automobiles 11-L
- Aerodynamics 14-L
- Calculating Drag Coefficient 23-L
- Mass Transportation 27-L

Materials-Handling Systems 1-M
- Robotics 4-M
- Pseudo Code (Programming a Robot) 11-M
- Automated Guided Vehicle 15-M
- Guiding Transportation Vehicles -- Automated Guided Vehicle 18-M
- Human Puck 24-M
- Pipeline 26-M

Water Transportation Systems 1-W
- Hull Design and Buoyancy 4-W
- Air Cushion Vehicles 6-W
- Submarines and Submersibles 10-W

Air Transportation Systems 1-A
- Airfoil Design 4-A
- Principles of Flight 9-A
- Rotary Wing Aircraft 11-A
- Lighter-Than-Air Vehicles 15-A

Space Transportation Systems 1-S
- Spacecraft Design 4-S
- Testing Rockets for Stability 6-S
- Lunar Rover 11-S
- Propulsion Problem Solving Activity 21-S

USING THIS PACKET

This packet contains technology-based learning activities for the Transportation Technology course at the orientation-level (grades 9 and 10) of the Illinois Plan for Industrial Technology Education curriculum project. These materials supplement the 1989 Illinois Plan Orientation Curriculum Guide and were developed to complement hands-on workshops.

The materials were designed to enable teachers attending the hands-on workshops to implement the activities at their home school. Workshop participants are encouraged to use the materials as a model for future curriculum development.

The Transportation Technology Activity Packet includes a course rationale, course mission, course description, course outline, suggested learning objectives for each of the transportation areas, and suggested learning experiences.* The packet also contains over twenty developed learning activities. Many of the activities have been collected from earlier activity packets developed by the project and past issues of **Technology News Today** (TNT) and The packet also contains several newly developed activities. These include activities like automated guided vehicles, rotary-winged aircraft, programming robots, wind tunnel testing rocket stability, calculating drag coefficiency, and testing air-foil designs.

When implementing these activities, it is important to teach the resources, technical processes, industrial applications, and technical impact for each technology education topic. By including content from each of these areas, students are ensured a complete orientation. Content should also address integrated skills like transition skills, generalizable skills, and vocational ethic skills, as well as the State Goals for Learning. The content can be presented through short lectures, discussion, media, or demonstrations. However, most of the time should be spent on hands-on learning activities.

The following abbreviations are used in this document:

TA = Teaching Aid
SH = Student Handout
DR = Drawing

Acknowledgment

The development of these materials were made possible through a grant from the Illinois State Board of Education, Department of Adult Vocational and Technical Education, Research and Development section.

* Information taken from the 1989 Illinois Plan Orientation Curriculum Guide.

TRANSPORTATION TECHNOLOGY

Course Rationale

Transportation, as we know it today, is considerably different than generations ago. The means by which people and goods are moved have evolved from slow moving humans and animal powered systems to sophisticated multi-purpose space shuttles. It seems as though humans constantly demand greater speed, efficiency, comfort, and safety in their vehicles. This has caused constant change and innovation in the way we guide, control, propel, and support our transportation systems.

Transportation is an important aspect of our society. People depend on the fact that there are choices available when they need to move themselves, others, or goods from one location to another. Many times, these choices are taken for granted. Our society takes for granted that they can be moved at will with random mode vehicles like cars, ships, and planes, as well as fixed route systems like trains, elevators, and escalators. We take for granted that pipelines will bring us water, provide natural gas, and dispose of sewage. This attitude has made our society quite dependent on transportation systems.

Because of this dependency, it is imperative that transportation technology be included in a student's educational experience, especially since 9th and 10th graders are becoming more active in the transportation system. Until this time in their lives, they have been primarily passengers rather than transporters. It is important that students understand that factors like quality, cost, space, efficiency, comfort, safety, and speed must be considered when selecting an appropriate mode of transportation. Studying Transportation Technology will place students in a better position to select the transportation system that will be most efficient, economical, and have the least detrimental impact on the environment.

Course Mission

The purpose of the Transportation Technology course is to orient students to the basic resources, technical processes, industrial applications, and technological impacts related to land, water, air, space, and materials-handling transportation systems. The course will help students to:

* use and understand the verbal and symbolic language used to describe transportation systems and phenomenon;
* develop and present creative solutions to present a future transportation problem;
* identify and investigate potential career opportunities in the area of transportation;
* understand the evolution of transportation technology and its influence on our culture; and
* safely use common tools, materials and processes to design, build, and test transportation systems.

Course Description

The Transportation Technology course includes units of land, water, air, space, and materials-handling transportation. Each unit will involve students in a wide variety of learning activities and experiences including things like designing an aerodynamic vehicle, building a submarine, evaluating wing designs, testing rockets for stability, and programming a pick-and-place robot.

Course Outline

In the spirit of orientation, students should be introduced to a wide range of transportation technologies. The following course outline lists the recommended units for either a nine or an eighteen week format. Potential lesson topics are provided under each unit title. Each lesson should embrace as many of the unit objectives as possible. In a nine week format, an emphasis should be placed on the terminology, resources, processes, applications, impacts, careers and safety concepts that relate to the lesson topics.

Sample Transportation Technology Course Content Outline

I. Introduction to Transportation Technology

II. Land Transportation
- A. Highway
- B. Off-road
- C. Rail
- D. Mass transit
- E. Support systems

III. Water Transportation
- A. Boats
- B. Surface effect ships (i.e., hovercrafts, hydrofoils)
- C. Displacement ships
- D. Submersibles
- E. Support systems

IV. Air Transportation
- A. Lighter-than-air
- B. Fixed winged
- C. Rotary-winged
- D. Support systems

V. Space Transportation
- A. Unmanned
- B. Manned
- C. Support system

VI. Materials-handling
- A. Fixed systems
- B. Variable systems
- C. Robotic
- D. Pipeline

Adapting the Transportation Technology Course Outline to Nine or Eighteen Week Formats

Hands-on learning activities are one of the most powerful ways of helping students learn about technology. Unfortunately, they are very time consuming. The following strategies can be employed to use available laboratory time more efficiently without sacrificing important unit objectives:

* Divide the class into small groups and assign each group a different learning activity related to the lesson topic. When each group has finished their assigned activities, have students present their experiences to the rest of the class. For example, during the materials-handling unit, have each group design, build, test, and present either a fixed path, variable path, pipeline, or robotic material handling system.

* Avoid assigning complex laboratory activities when simpler activities will enable students to experience important concepts and achieve the desired objectives. For example, during the land transportation unit, have students make and test wind tunnel mock-ups for an aerodynamic vehicle out of clay instead of wood.

* Prepare work stations that organize the tools and materials needed to conduct laboratory activities prior to class. For example, during the space transportation unit, develop rocket kits that students can assemble and test.

* Have students experience a wide range of concepts through one or two robust learning activities. For example, during the air transportation unit, have students design, build, and test a glider. Discuss how the basic parts of an air transportation system (i.e., propulsion, control, guidance, payload, supports) transfer to other lighter-than-air, fixed winged, and rotary winged aircraft.

During an eighteen week format, students can engage in more complex learning activities and experiences, given topics in greater depth. In addition, there is an opportunity to provide a wider range of learning experiences. The study of technology allows for an infinite number of learning experiences. Therefore, it is important to select and implement learning activities in an efficient manner.

INTRODUCTION TO TRANSPORTATION TECHNOLOGY

INTRODUCTION TO TRANSPORTATION TECHNOLOGY

Suggested Learning Objectives

Upon completion of the Introduction to Transportation Technology unit, students will be able to:

A. Define and properly use common transportation technology terminology like combustion, pathways, velocity, vehicle, mode, payload, and terminal.

B. Categorize modes of transportation such as land, water, space, air or materials handling transportation systems.

C. Categorize transportation systems such as fixed or variable path transportation systems.

D. Categorize turbines, four cycle, diesel, Wankel, Sterling, and steam engines as internal or external combustion engines.

E. Describe the propulsion, control, guidance, payload, and support systems for various land, water, space, air and materials handling systems.

F. Describe the basic applications for transportation technology including moving people, transporting goods, and facilitating recreation.

Suggested Learning Experiences

1. Explain how transportation systems have control, propulsion, payload, guidance, and support subsystems. Using materials like balloons, clothes pins, straws, paper clips, straight pins, fishing line, and masking tape, have students design, build and test a vehicle that will carry a payload a significant distance (15 to 25 feet). Ask the students to describe the control, propulsion, and guidance subsystems on their transportation system and compare them to those used on real transportation systems.

2. Introduce students to a variety of transportation systems. Include things like bicycles, trains, barges, super tankers, commercial aircraft, helicopters, rockets, space shuttles, pipelines, conveyers, and robots. Assign each student a topic and ask them to develop a display describing a mode of transportation. Each display should identify if the transportation system is a land, water, air, space, or materials-handling system and is fixed or a variable path system. In addition, each display should describe the transportation system's propulsion, control, guidance, payload, and support subsystem.

TRANSPORTATION TECHNOLOGY
KEY CONCEPTS

GUIDANCE SYSTEMS

Information sources used by the operator to make decisions about a vehicle's speed, direction, and/or location.

CONTROL SYSTEMS

Manipulations made by the operator to change or maintain a vehicle's speed and direction.

PROPULSION SYSTEMS

The part of the vehicle that produces the power. The type of propulsion system used for a particular vehicle depends on its function, size, speed, acceleration requirements, and range.

PAYLOAD SYSTEMS

The part of the vehicle that is designed to protect and hold people and/or products.

TRANSPORTATION PROBLEM SOLVING

Introduction

In this lab activity, students will begin to experience two concerns in transportation; propulsion and guidance systems. Students will also begin to experience the problem solving activities prevalent throughout the area of Transportation Technology. Students will create an experimental vehicle out of miscellaneous materials which will solve a given problem.

Materials and Supplies

For this lab activity, students will work in groups of two. You will need the following materials for each group:

* 2 soda straws
* 3 balloons
* 2 straight pins
* 1 sheet of 8 1/2" x 11" construction paper
* 4 rubber bands
* 2 paper clips
* glue
* tape
* 1 plastic bag to hold items listed above
* fishing string

PROBLEM STATEMENT

Problem Statement I

Using the materials you were given, design and construct a vehicle that will travel under its own power or under a self-contained power source. The vehicle must carry a payload (clothes pin) a distance of twenty feet in a relatively straight line from the starting point. You may use only the materials contained in the packet. Materials may be modified by combining, forming, or separating. Success will be determined by the vehicle reaching its destination in the shortest possible distance.

Problem Statement II

Using materials you were given, modify your vehicle from Problem Statement I to travel twenty feet, carry a payload and self-destruct upon impact. Success will be determined by the vehicle reaching its destination in the shortest possible distance and then self-destructing upon impact.

Activity Procedures

1. Read the problem statement and formulate in your own mind what is necessary to construct a solution.
2. Be creative. You have been given limited materials but you have been given unlimited possibilities to solve the problem.
3. Consider various ways to propel and guide your vehicle.
4. Upon successfully solving Problem I build upon your success by attempting to solve Problem II.
5. If your first attempt is not successful, do not give up. Remember, almost all inventors experience some type of failure.before they finally succeed.
6. Keep your ideas to yourself. You wouldn't want to "leak" corporate secrets.

Activity Analysis

1. What two mechanical systems must be considered in order to solve the problems on the problem statement?

   a. _____

   b. _____

2. Identify a propulsion system for the following transportation vehicles.

Type of Vehicle	Propulsion System
Automobiles	_____
Ship and Boats	_____
Trains	_____
Space shuttles	_____

3. Identify guidance systems for the following transportation vehicles.

Type of Vehicle	Guidance System
Automobiles	_____
Pleasure crafts	_____
Oil Tankers	_____
Aircraft	_____
Spacecraft	_____

PROPULSION

Introduction

Newton's third law plays a major role in understanding how many propulsion systems work. Newton's third law states for every action there is an equal and opposite reaction. Newton's third law forms the basis for various propulsion systems like jet turbines on aircraft, thrusters on rockets, and propellers on ships.

This series of Technology Education Activities will allow students hands-on experience with Newton's third law.

ACTIVITY ONE

Materials and Supplies

* 1 chair with wheels
* 1 weighted medicine ball

Activity Procedures

1. Each group of two should obtain a medicine ball and a chair with wheels.
2. Have one group member sit in a chair, while another member stands in front of them.
3. While sitting in the chair, push the medicine ball to the person standing. What happens?

_____

_____

4. Using this technique, take turns moving around the room.

Activity Analysis

1. Explain why the chair moved.

_____

_____

2. How is this same principle used to move and transport people and goods?

_____

_____

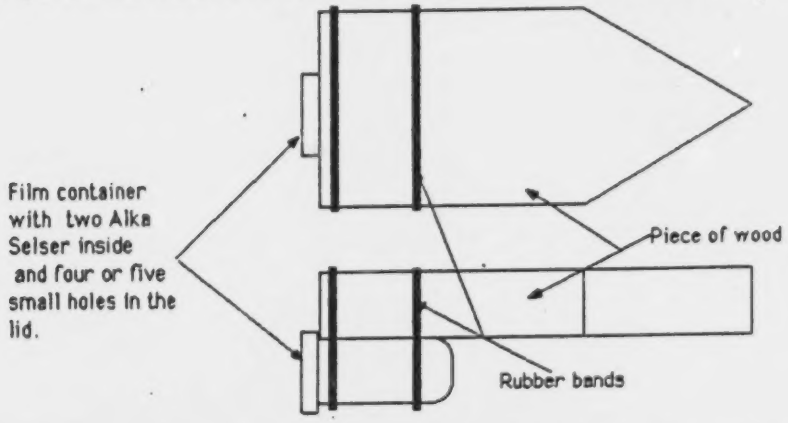
ACTIVITY TWO

Materials and Supplies

* 1 plastic film container (Put 4 or 5 small holes in the lid)
* 1 plastic or metal container, approximately 1" deep x 3" wide x 5" long (a piece of wood will also work)
* Several Alka Selser
* 1 plastic container (test tank) approximately 5" deep x 12" wide x 24" long.
* 2 rubber bands

Activity Procedures

1. Each group of two or three should obtain the materials described above.
2. Using the materials provided, construct the vessel shown below.



3. Once the vessel is constructed, place two Alka Selser in the film container and fill the container with water.
4. Then, place the vessel in the test tank.
5. Observe what happens.

Activity Analysis

1. Describe what happened to the vehicle.

_____

_____

2. Describe why the vehicle moved.

_____

_____

3. List other transportation vehicles that use the same principle for propulsion.

_____

_____

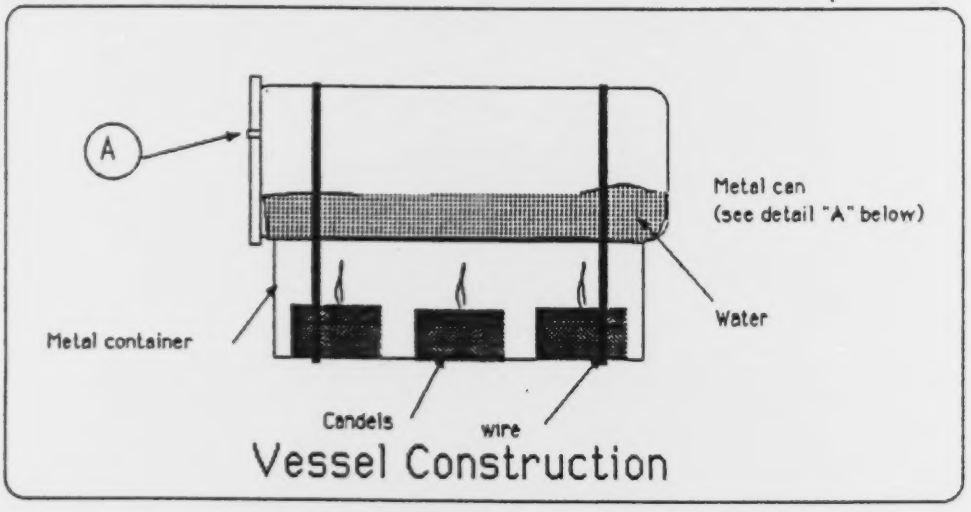
ACTIVITY THREE

Materials and Supplies

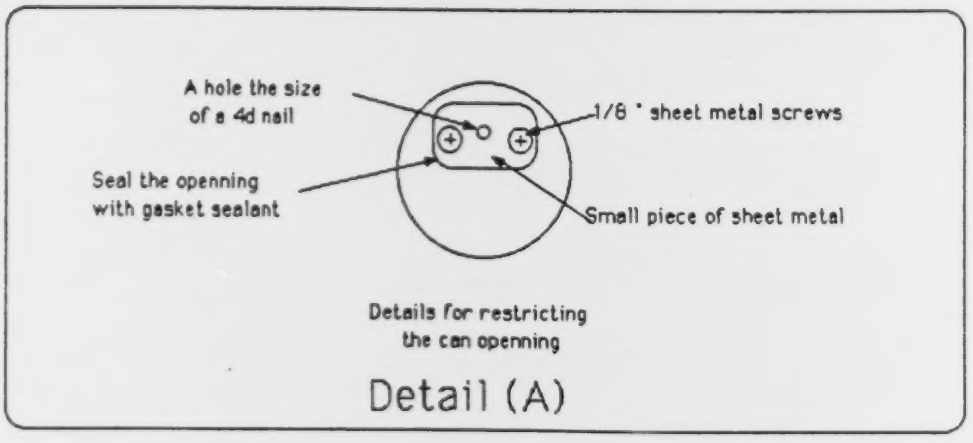
* 1 12 fluid ounce metal container (e.g., soda can, vegetable or fruit juice can)
* 1 metal container approximately 2" deep x 3" wide x 4" long
* 2 or 3 candles, 1/2" tall x 1" diameter
* Matches
* 1 plastic container (test tank) approximately 5" deep x 12" wide x 24" long
* 14 gauge copper or steel wire (solid core).

Activity Procedures

1. Each group of two or three should obtain the materials described above.
2. Using the materials provided, construct the vessel shown below.



Vessel Construction



Details for restricting
the can openning

Detail (A)

7-I

3. Once the vehicle has been constructed, place it in the container of water.
4. After obtaining your instructor's permission, carefully light the candles. Make sure the candles are directly under the vessel.
5. Observe what happens to the vessel.

Activity Analysis

1. Describe what happened to the vessel.

_____

_____

2. Describe why the vessel moved.

_____

_____

3. List other transportation vehicles that use the same principle for propulsion.

LAND TRANSPORTATION SYSTEMS

LAND TRANSPORTATION SYSTEMS

Suggested Learning Objectives

Upon completion of the land transportation unit, students will be able to:

A. Define and properly use common land transportation **terminology** like payload, combustion, suspension, containerization, and mode.

B. Describe the **processes** used in land transportation like routing, dispatching, steering, directing, switching, towing, hauling, scheduling, loading, unloading, and fueling.

C. Identify the basic natural, human, material, financial, technological, and informational **resources** used in land transportation processes and enterprises (e.g., petroleum products, drivers, pathways, maps).

D. Identify basic **applications** for land transportation systems including transporting people and goods, and recreation.

E. Identify the milestones in the **history** and evolution of land transportation technology including the development of the wheel, James Watt's steam engine, and the French TGV super train. SS2

F. Identify and evaluate **career** opportunities in land transportation (e.g., truck dispatcher, civil engineer, topographer) based on their interests, talents and career expectations.

G. Describe the environmental and societal **impacts** associated with various land transportation technologies including urban sprawl, air pollution, land utilization, accidents, and noise. SC2

H. Identify the **safety** considerations and adhere to the safety practices associated with various modes of land transportation. PH3

I. Identify basic modes of land transportation including bicycles, trains, buses, automobiles, motorcycles, and trucks.

J. Identify and describe the basic systems within an internal combustion engine including the mechanical, lubrication, fuel, cooling, and ignition systems.

K. Describe the basic payload, guidance, propulsion, control, and support systems for a given mode of land transportation.

L. State the concepts, vehicles, support systems, and techniques used in intermodal transportation and how containerization saves time, money, and energy.

M. Determine the optimum means of transporting a given payload based on departure, destination, cost, time, energy, safety, and environmental considerations.

N. Design, build, test, and evaluate a transportation system that addresses a transportation problem based on cost, time, energy, environmental, and/or societal considerations.

O. Apply basic mathematical concepts to do things like determining a vehicle's speed, calculating energy utilization, and comparing vehicle specifications. MA1

P. Conserve energy, reduce congestion, and minimize waste by utilizing appropriate transportation technologies to transport people and goods from one location to another.

Q. Forecast the potential effects of America's dependence on automobiles and trucks on energy utilization, air pollution, transportation costs, and urban congestion.

Suggested Learning Activities

1. Introduce students to the payload, guidance, propulsion, and control systems used in automobiles. Have students design, build and test a model car powered by a CO_2 cartridge, spring, or electric motor. Determine the relationships between aerodynamics, vehicle weight, energy used, and speed. Ask students to describe how they addressed current and future trends in automobile design when they designed their model.

2. Explain how automotive engineers, designers, and technologists solve problems by developing experimental vehicles. Provide students materials and components like pipe, wheels, sprockets, and chain. Have students design, build, and test an experimental energy efficient vehicle that is powered by a gasoline engine, an electric motor or a human. Calculate the amount of energy required to propel the vehicle a given distance. Discuss the aerodynamic, structural, payload, and propulsion variables that make land transportation vehicles more energy efficient.

3. Discuss the importance of aerodynamics when designing land transportation vehicles. Have students design and make mock-ups for futuristic automobiles, trucks, and trains. Use a commercial or constructed wind tunnel to test and evaluate each mock-up. Compare test results and mock-up designs to identify the characteristics of an aerodynamic vehicle. Ask students to identify aerodynamic features on photographs of up-to-date automobiles, trucks, and trains.

4. Discuss the need for public transportation in urban areas. Provide teams of students large simple maps featuring residential, commercial, and industrial areas and a problem statement describing how many people need to be transported from location to location at various times of the day. Have students build and present models describing a public transportation system using a car pool, commuter rail, personal rapid transit, or bus system. Make sure each presentation addresses cost, energy, societal, and environmental considerations. Ask students to evaluate the advantages and disadvantages of using multi versus single passenger transportation technologies.

5. Invite a professional truck driver to talk to your class about transporting goods by truck. Have the speaker address payload, weight, inspection, legal, maintenance, fuel, insurance, cost, and safety considerations associated with transporting goods by truck.

6. Discuss the structural techniques used to build bridges for various applications. Include concepts like load, span, tension, compression, suspension, cantilever, arch, and truss. Provide students a problem statement describing the specifications for making model bridges (i.e., length, width and height). Using easy-to-work materials, have students design and build a small model bridge. Place each bridge in a fixture and suspend a load from a given point on each structure. Increase the load until the bridge breaks. Have students analyze how each bridge carried and transferred the load and if it failed, why it did so.

7. Introduce students to the super trains used in Japan, France, and the United States and discuss what makes them an innovative form of transportation. Using common and easy- to-work materials, have teams of students design, build and present a working model for a rail system based on MAGLEV, tracked air cushion, monorail, or evacuated tube technologies. Have students identify and discuss the practical and technological problems associated with super train technology.

8. After introducing the internal combustion engine, have teams of students disassemble and inspect an automobile or small engine. Have students describe the mechanical, ignition, fuel, cooling, and lubrication systems and how they work together to convert chemical energy into mechanical energy. Discuss how each of the basic systems identified apply to other types of engines used on land transportation vehicles.

9. Discuss the safety features and devices used in new automobiles. Provide students a simple vehicles that will carry an egg down a ramp. Have students use things like weather stripping, rubber bands, springs and balloons to modify the vehicle so it can travel down a ramp and strike a rigid object three consecutive times without breaking the egg. Ask students to explain and discuss how the strategies they used to protect the egg apply to things like air bags, seat belts, energy absorbing bumpers, and padded dash boards.

10. Discuss the milestones in the history and evolution of land transportation. Assign each student a historical event. Using library resources, have students gather information and develop an abstract describing the people, dates, places, and impacts associated with their assigned event. Encourage students to illustrate their abstracts. Post each abstract on a large timeline. Ask students to describe how given events influenced our culture and subsequent technological developments.

11. Discuss the career opportunities in land transportation systems. Include occupations at the non-skilled, semi- skilled, skilled, technician, and professional levels in the discussion. Using library and guidance resources, have students gather information and present a short written or verbal report about an occupation related to land transportation systems. Each report should include information about the educational requirements, working conditions, benefits, salary, and advancement potential related to the occupation. Ask students to evaluate the career based on their interests, talents, and career expectations.

CONTROLLING TRANSPORTATION VEHICLES
RADIO-CONTROLLED VEHICLE

Introduction

There are many ways to control various transportation vehicles. One area growing in importance is radio control. The Defense Department uses radio control to maneuver pilotless, or drone aircraft. Radio control is used by NASA to position satellites and deep space probes. In some police departments, radio control is combined with video cameras and robots to remove potentially explosive materials.

Radio control uses a transmitter to send a signal to a receiver. The receiver sends a signal to various servo motors. The motors can be used to cause a vehicle to turn left, right, go forward, backwards, slow, fast, stop, and go. If placed in an aircraft, the servo motors, via radio signals, can cause the plane to climb, dive, speed up, slow down, bank left, and bank right.

This Technology Education Activity will provide students the opportunity to use a radio-controlled vehicle to simulate how remote-controlled vehicles can be used in hazardous areas and situations.

Materials and Supplies

Each group of two will need the following materials:

* One radio-controlled vehicle
* Access to a scale model of plant layout (DR #1)

Problem Statement

The Remove It Company specializes in removing hazardous materials from dangerous situations. A local chemical plant has had containers holding toxic materials rupture in a remote part of their facility. Five employees have been trapped in a control near the ruptured container. Because of the toxic nature of the material, the employees can not be rescued until the container is removed. It is your job to remove the container by means of radio control and place it in a secure place.

Activity Procedures

1. Obtain the materials necessary to complete the activity.
2. Study the scale model (DR #1).
3. Plan the most direct route to the container.
4. Using the radio-controlled vehicle, retrieve the container.
5. After you have retrieved the container, exit the plant and place the material in the decontamination area.

Activity Analysis

Based on the experience gained by conducting this activity:

1. What are the advantages of using radio-controlled vehicles for hazardous waste removal?

_____

_____

_____

2. What are the disadvantages of using radio-controlled vehicles for hazardous waste removal?

_____

_____

_____

3. What are future applications for radio-controlled vehicles?

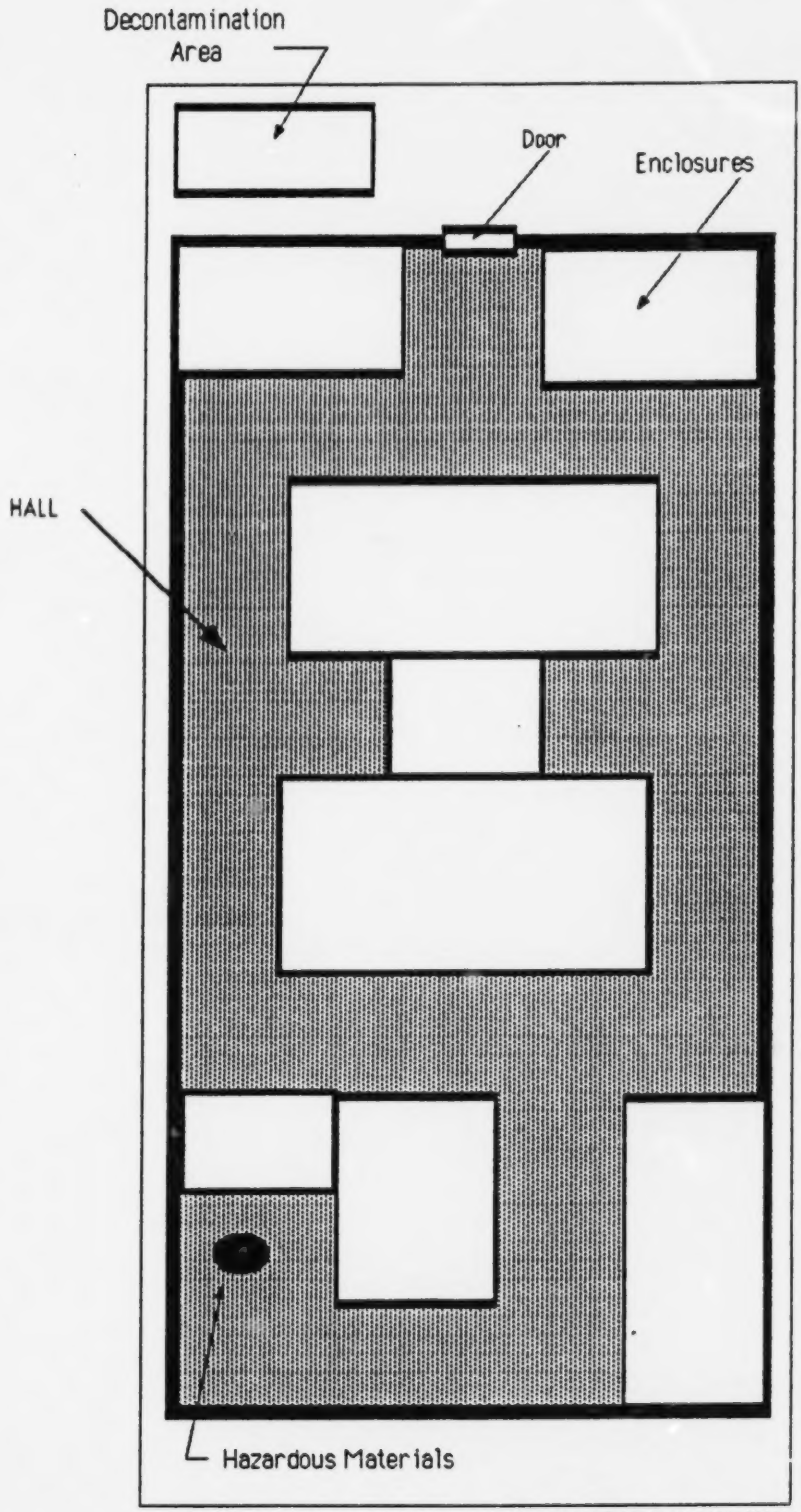
_____

_____

_____

Plant Layout

DR #1



TWO-SPEED TORQUE RACER

Taken from TNT (September, 1989)

Introduction:

The two-speed torque racer is based on a learning activity submitted to the Illinois Plan for Industrial Technology Education Project by Rick Bunton of Mid-County High School in Varna, Illinois. Inspired by a display of wooden toys in a craft show, Rick decided a toy car powered by a rubber band could be used to teach students concepts like propulsion, mechanical advantage, torque, power, potential energy, and rate. The cars proved to be a powerful and appropriate teaching tool because they can be made out of scrap materials in a reasonable period of time. In addition to being the focus of a laboratory activity involving time trials and simple calculations, students could compete with one another in the context of a mock drag race.

Materials and Equipment

* One piece of 3/4" x 4" x 7" wood
* Four 2" diameter, 1/4" hardboard wheels
* Two 1/4" dowel rods, 4 3/4" long
* Four 1/8" dowel rods, 3/4" long
* One 1" dowel rod, 3/4" long
* Four 1/4" washers
* Three 2" x 1/8" rubber bands
* One 2" hole saw
* Two small eyelet screws
* One 20' long piece of fish line (6 lb. test)
* One spring scale (5 lbs. or 72 ozs.)

Making a Torque Racer (DR #1)

1. Using an appropriate drill bit (1/4" or 17/64"), drill holes in the edge of the 3/4" stock for axles. Cut the wood to shape using the illustration as a guide. Drill two 1/8" holes in the face of the board just in front of the rear axle opening and approximately 1" apart. These holes will be used to mount 1/8" dowels which will hold the rubber bands in place. Install a short piece of 1/8" dowel rod in each hole.
2. Using a 2" hole saw with a 1/4' arbor bit, cut out four wheels from a small sheet of 1/4" hardboard. You will need a fixture to sand the edges of the wheels. To make the fixture, fasten a 3/8" dowel rod to a lathe or drill press. With the machine running, file a taper into the dowel rod so it will accept the wheels. Slide each wheel on to the tapered dowel to achieve a friction fit, turn on the machine, and carefully sand the edges until smooth.
3. Place a piece of 1" dowel rod in a machine lathe. Using a center drill chuck and a 1/4" bit, drill a hole though the center of the 1" dowel rod. Using the illustration as a guide, drill a 1/8" hole in the side of the 1" dowel rod and install a short piece of 1/8" dowel rod in the hole. Place the 1" dowel rod in the rear axle opening of the car. Slide the axle through the chassis and the 1" dowel. Locate the position for a 1/8" dowel rod in the axle. Remove the axle and drill a 1/8" hole in the marked location. Reinstall the axle through the chassis and the 1" dowel rod. Glue the 1" dowel rod in place and install a short 1/8" dowel rod in the hole on the axle.

4. Slip a washer over the ends of the axle and install and glue the wheels. Slide an axle through the front axle holes, and install the front washers and wheels. Turn the car over and install two eye screws in the bottom. Locate one in the center of the chassis toward the front of the car and one in the center of the chassis toward the rear of the car.

Activity Procedures and Analysis

Most land vehicles use an engine to create the rotational force needed for propulsion. To gain the mechanical advantage needed to transport heavy loads or to achieve given speeds, the rotational force from the engine is typically transmitted through some form of transmission mechanism. It typically uses a series of gears, pulleys and belts, or sprockets and chains to convert a large force exerted over a short distance into a smaller force exerted over a longer distance. In contrast, it can also be designed to convert a small force exerted over a long distance into a larger force exerted over a shorter distance.

The model car uses a rubber band to provide the force needed to propel the vehicle. To determine the amount of force being applied to the drive mechanism, hook the rubber band with a spring scale and stretch it to five inches. Read the scale and enter the value in pounds in the space below.

Force applied by the rubber band = _____ lbs.

Torque is the amount of rotational force applied to a shaft through a lever. To calculate the amount of torque applied to the rear axle in the first transmission setting, multiply the amount of force applied to the drive mechanism by the rubber band, times the radius of the rear axle (i.e., .125"), plus the radius of the 1" dowel rod (i.e., .5"). Enter your answer in the space below.

Torque in Setting #1 = _____ lb./in.

Next, calculate the amount of torque applied to the rear axle in the second transmission setting by multiplying the amount of force applied to the drive mechanism by the rubber band times the radius of the rear axle (i.e., .125"). Enter your answer in the space below.
Torque in Setting #2 = _____ lb./in.

Theoretical mechanical advantage is the amount of force applied to a machine (input) versus the amount of force produced by the machine (output). To calculate the mechanical advantage of transmission setting #1, divide the radius of the drive wheel (i.e., the 1" dowel rod, .5") by the radius of the driven wheel (i.e., the 2" wheel, 1"). Enter your answer in the space below.

Mechanical Advantage of Setting #1 = _____

Calculate the mechanical advantage of transmission setting #2 by dividing the radius of the drive wheel (i.e., the 1/4" axle, .125) by the radius of the driven wheel (i.e. the 2" wheel, 1"). Enter your answer in the space below.

Mechanical Advantage of Setting #2 = _____

Based on your calculations, predict which transmission setting will propel the vehicle the furthest.

A. transmission setting #1

B. transmission setting #2

Predict which transmission setting will propel the vehicle off the starting line the fastest.

A. transmission setting #1

B. transmission setting #2

To test these predictions, thread the fishing line through the eyelet screws and run the fish line the length of the test track. Tape the end of the fish line to the floor. Use a couple of 3/4" pieces of scrap to space the fish line off the floor and to establish some tension. Place a rubber band around the dowel rod on the chassis and the dowel rod protruding from the 1" dowel on the axle. Rotate the rear wheel clockwise one revolution, place the car on the floor, and let it go. You may want to measure the amount of time it takes for the car to travel a given distance (e.g. 10 ft.). Repeat the process using transmission setting #2 to propel the vehicle. However, this time, you will need to rotate the rear wheel 7.5 revolutions to apply the same amount of force to the drive mechanism. Place the car on the floor, let it go, and observe the difference, and answer the following questions.

What effect does transmission setting #1 have on the vehicle's performance?

_____

_____

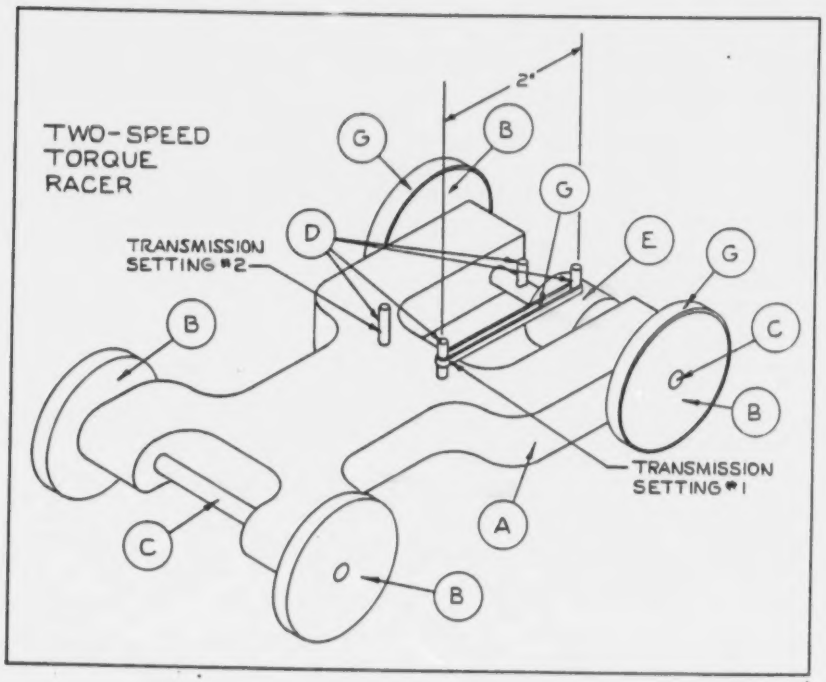
_____

What effect does transmission setting #2 have on the vehicle's performance?

_____

_____

_____


TWO-SPEED
TORQUE
RACER
2"
G
B
G
D
TRANSMISSION
SETTING #2
E
G
B
C
B
TRANSMISSION
SETTING #1
A
C
B

DESIGNING SAFE AUTOMOBILES

Introduction

Automobiles have given people the ability to travel long distances. This freedom has had its price. Each year, thousands of people are killed and injured as a result of automobile accidents. Because of this, automotive safety design has become a major part of the auto industry.

This Technology Education Activity will allow the students to assume the role of a safety engineer.

Materials and Supplies

Provide each group of two or three students the following:

* One crash vehicle (DR #1)
* Test ramp (DR #2)
* Assorted springs, rubber bands, sponge rubber, weather stripping, balloons, cotton balls, 1/8" metal rods for construction safety devices.
* Plastic sandwich bags (body bags)
* Plastic eggs (practice passengers)
* Raw eggs (live passengers)

Problem Statement

You are an employee of a major automobile manufacturer in the safety engineering department. Your group has been given the task of designing and installing safety devices for a new test vehicle. The vehicle must be able to roll down an eight foot ramp three times into an immovable object, (e.g., block wall, concrete block) while protecting the passenger (raw egg) from injury.

Activity Procedures

1. Obtain the materials needed to complete the activity.
2. Using the materials provided by the instructor, install a safety system for the vehicle. Remember, you can add to the test vehicle, but you may not modify the basic structure.
3. Once your group feels they have a safety system that will work, use the practice passenger (plastic egg) to test your design.
4. If necessary, make modifications.
5. Once all tests and modifications have been completed, test your design using a live passenger (a raw egg). In the unlikely event the safety system fails to fully protect the passenger, place the egg into a plastic bag (body bag) before installing it in the vehicle. This will make the clean-up much easier.
6. Place your vehicle at the top of the ramp and let it roll freely into the immovable object. Repeat this procedure three times. Examine the egg after each test run. Remember, a crack in the egg constitutes an injury or death to the passenger.
7. Continue to refine your vehicle until it can sustain three consecutive tests without damage to the passenger.

Activity Analysis

Based on the experience gained by conducting this activity:

1. Which safety devices seemed to be most effective?

_____ _____

_____ _____

_____ _____

_____ _____

2. Identify safety devices used on today's automobiles.

_____ _____

_____ _____

_____ _____

_____ _____

_____ _____

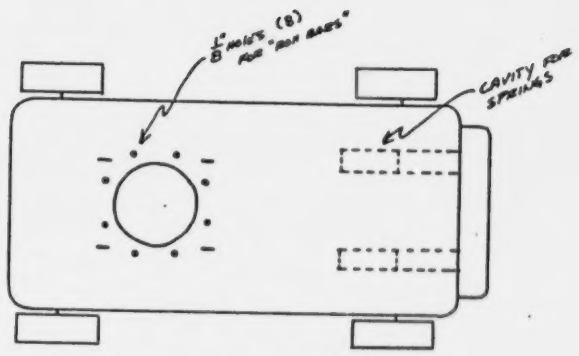
_____ _____

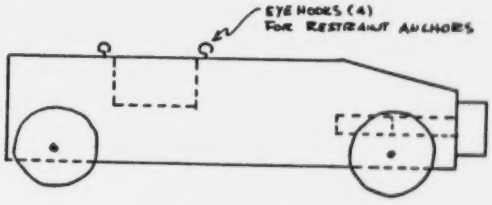
_____ _____

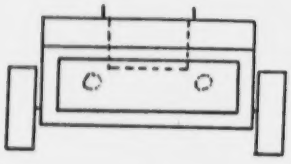
3. Categorize the items listed in Question #2 as either restraint or energy absorbing devices.

Restraint	Energy Absorbing
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

DR #1





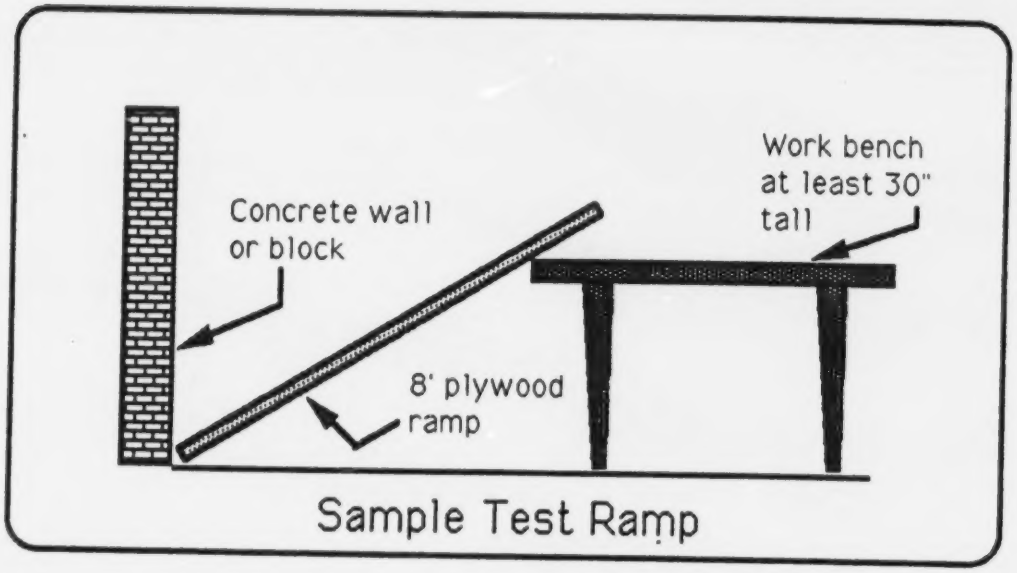


CRASH VEHICLE

MATERIALS LIST

1 - 2x4x9 BLOCK
4 - WHEELS 1 - 1½"
ASSORTED:
SPRINGS
BALLOONS
RUBBER BANDS
WEATHER STRIPPING
⅛" METAL ROD
2 - ⅜ DOWELS
4 - SMALL EYE HOOKS

DR #2



Sample Test Ramp

13-L

AERODYNAMICS

Making a Simple Aerodynamic Vehicle

Introduction

Aerodynamics is the effect of air flow and the forces involved when an object moves through air or when air moves past an object. The flow of air moving around a vehicle is called streamline. The body shape that allows air to move around it with the least amount of resistance is called streamlined.

Vehicles that travel below the speed of sound have less resistance if they are rounded in the front, and tapered off to a point in the rear (teardrop shape). A body with an overall rounded or square shape will cause air to break away from the streamline into swirls of air called vortices. Air movement caused by a vortex is uneven or turbulent, and slows down the vehicle. This effect is called drag. An even greater factor affecting drag is speed. If the speed is doubled (30 to 60 mph) the amount of drag is increased four times. As much as 70% of an automobile's energy consumption is expended to overcome aerodynamic drag.

Sir Isaac Newton developed the principle of relative motion in 1865. This makes it possible to test the principles of aerodynamics by mounting a model in a wind tunnel and measuring the effects of the airstream forced in the tunnel. The first wind tunnel was constructed in England during 1871. In the United States, the Wright Brothers constructed their own wind tunnel in 1902, and applied the test results to their airplane designs. In 1980, General Motors Corporation completed the first full-scale wind tunnel for testing automobile and truck designs. These tests are conducted from the early clay model stages through the finished prototype. One of the principle purposes is to learn how to reduce aerodynamic drag.

With the need for fuel conservation, aerodynamics is playing an increasing role in automotive design. In the early 1980's, rising fuel costs forced American automakers to change their designs to more efficient shapes. Producing a car with smaller engines, lighter frames and a good drag coefficient (CD) is the top priority of automobile designers. Even a small reduction in drag can result in a large increase in fuel economy and performance.

In this activity, you will construct a vehicle that will be placed in a wind tunnel to demonstrate air flow around the body of the vehicle. This demonstration will show the effects that design has on the vehicle's air resistance.

Materials and Supplies

* Computer and monitor
* Computer aided engineering program (e.g., Car Builder)
* Scissors
* Balsa wood 12" x 2 3/4" x 1 5/8
* Coping saws, files, surforms, sandpaper
* Wind tunnel (see DR #1)
* Pencils
* Dry ice
* Straws
* Carbon paper

Problem Statement

An important consideration in designing a vehicle is aerodynamics. Aerodynamics is the effect of air flow on objects as they pass through the air. Aerodynamics has taken on new importance since the need for more fuel efficient vehicles. A poorly designed vehicle uses more fuel. Vehicles should be designed to cut through the air to reduce drag. Aerodynamics can be tested with the aid of a wind tunnel. As the wind passes over the vehicle the line of distortion can be seen with either the use of smoke or special fluids. The design can then be modified to eliminate the distortion.

You are an automotive design engineer in the research and development department of the Maxell Automotive Company. You have been assigned the task of designing the new fuel efficient, aerodynamically sound, stylish and futuristic automobile for the company. For the past several years, the company has been losing money to foreign competitors. Success of your design could mean the success or failure of the company. You will be in charge of the designing, constructing, and testing of the new prototype.

Procedure

1. Preparation for constructing the prototype vehicle:

   A. Review all the information presented by your instructor.
   B. Compare car, truck and train designs of ten or more years ago with today's designs.

   OPTIONAL:

   C. Go through the computer aided engineering program (e.g., Car Builder)provided by your instructor. Design, test, and evaluate an automobile design. Modify the design and run a final test on the vehicle you design.

Layout and Drawings:

1. Obtain three rough sketch planning sheets (SH #1 from the teacher).

2. The first step in the design process is to develop several rough sketches. You should not rely on just one design at this point. Develop at least three different designs. Be sure to draw the top and front views. Be creative.

3. Once you have developed three sketches, it is time to refine your drawings.

4. To refine your sketches, obtain some graph paper (SH #2) from your teacher.

5. Choose your best design and very neatly draw the design in the space provided. This sketch will become a pattern later, so be very accurate.

CONSTRUCTING A BALSA WOOD OR WOOD MODEL:

A. Obtain carbon paper, scissors, poster board and tape from the instructor. If you built a prototype (see optional activity) and did not change the shape of the car, the next four steps are not needed.

B. Tape the side design pattern on top of the carbon paper. Lay the carbon paper and design on top of the poster board and trace out the design.

C. Carefully cut out the design.

D. Using the cut out piece of poster board as a template, tape it on the side of the wood and trace the pattern.

E. Once the pattern has been drawn onto the wood, use the band saw and very carefully cut out the shape of the car. **NOTE: Obtain permission from the instructor before operating any equipment.** Take your time.

F. Using a wood rasp, wood file, and rough sand paper (60-80 grit), shape your car.

G. Once you have obtained the desired shape, smooth with medium sand paper (100-120 grit).

H. Finish sanding with a fine sand paper (220 or 240 grit).

INSTRUCTIONS FOR MAKING CLAY MODEL PROTOTYPE (Optional activity)

A. Obtain enough clay to make a 9" x 3" x 3" rectangle, carbon paper, 9" x 3" piece of poster board, tape, scissors, and a pointed object such as a pencil.

B. Shape the clay into a 9" x 3" x 3" rectangle.

C. Place the carbon paper on top of the poster board. Tape the side design pattern on top of the carbon paper and carefully trace the design. Be as accurate as possible.

D. Carefully cut out the design.

E. Do not throw away the top half of the template as it can be used as a gauge to see how close you are to the original design. Permanent patterns and gauges can be made of Masonite.

F. Place the pattern on one side of the clay. Using the point of a sharp object, such as a pencil, trace the design. Repeat for the opposite side. Be sure the two patterns match.

G. Using a knife, cut away the excess clay to obtain the desired shape. Use the gauges to check accuracy.

H. Make sure the surface of the prototype is very smooth.

I. Check to see if the wheels will fit within the desired design. If your car design is such that the wheels are exposed, locate and assemble the wheels and axles.

J. Obtain final approval for your design.

K. NOTE: The clay model is very easily damaged. Therefore, handle and store with care.

TESTING VEHICLE FOR AERODYNAMIC DESIGN

1. Test the vehicle's aerodynamic design in the wind tunnel. The wind tunnel will show the air flow patterns over the vehicle's surface. By using smoke, lines of distortion will become visible. These lines of distortion are called eddie currents.

2. Recording your observations on SH #3, conduct the following steps:

   A. Place the vehicle on the pallet and slide the pallet into the wind tunnel until it is visible in the wind tunnel window.

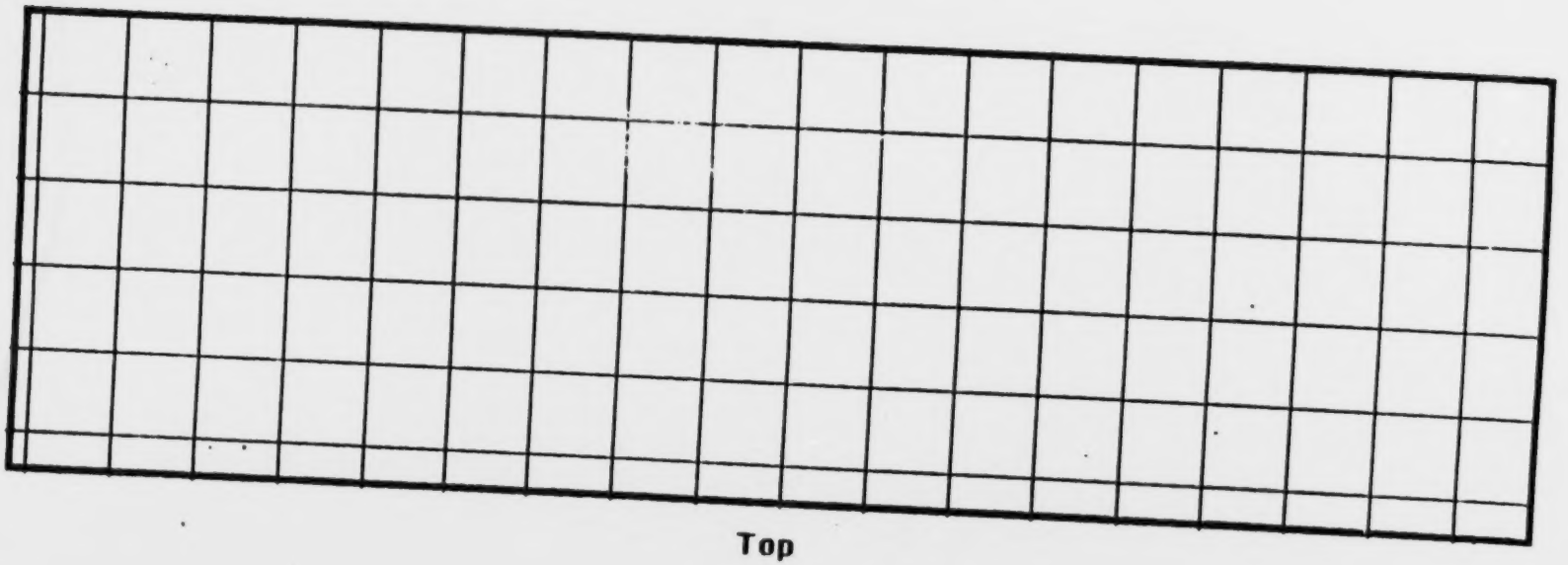
   B. Place a small amount of warm water and dry ice into the end of the wind tunnel that has the straws. (Be sure to obtain your instructor's permission before completing this step.)

   C. Place a small fan at the other end of the tunnel, making sure that the fan is pulling the air out.

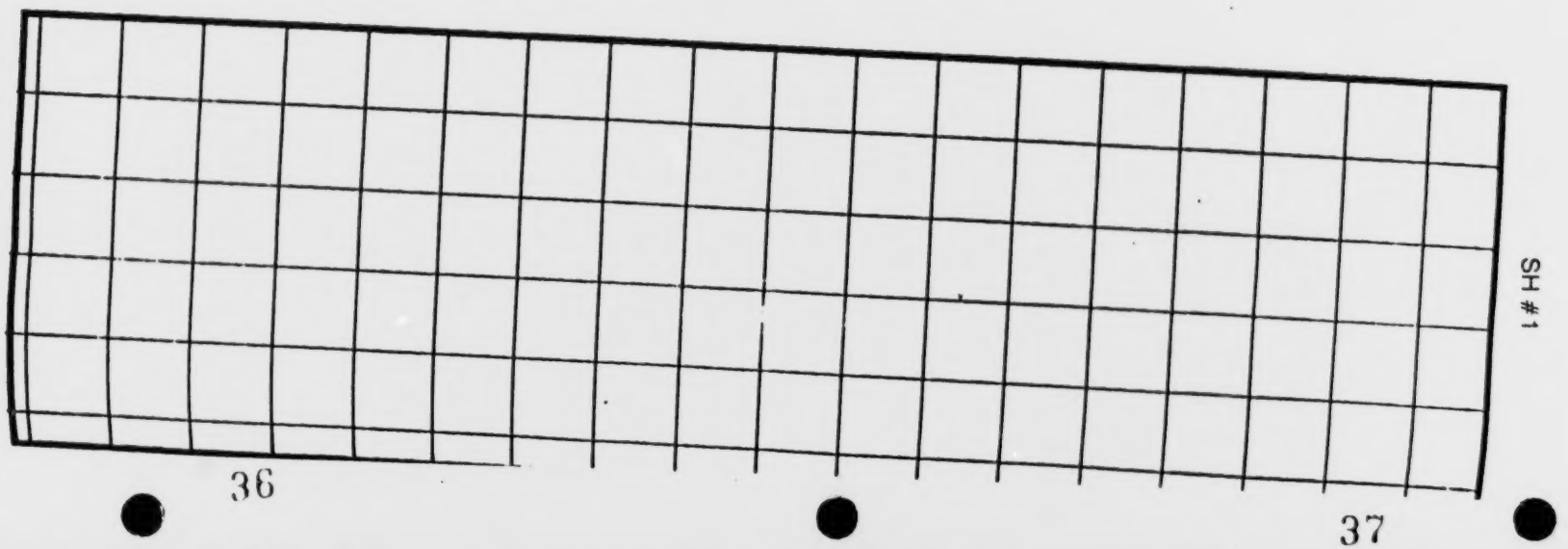
   D. Obtain the Wind Tunnel Performance Sheet (SH #3) from your instructor. Watch the flow of smoke as it moves over the vehicle. Draw your vehicle and sketch the smoke flow pattern. Make sure you identify all areas of turbulence.

   E. Write a short description, stating the changes and recommendations needed to improve the aerodynamic designs.

Rough Sketch



Top

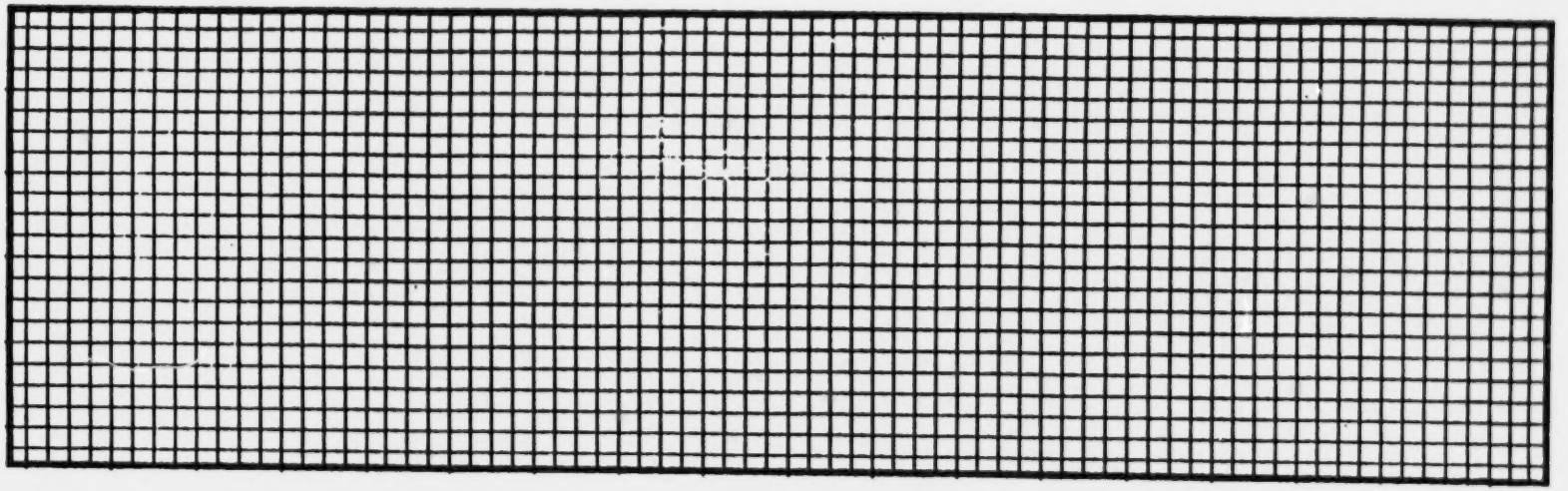


SH #1

36

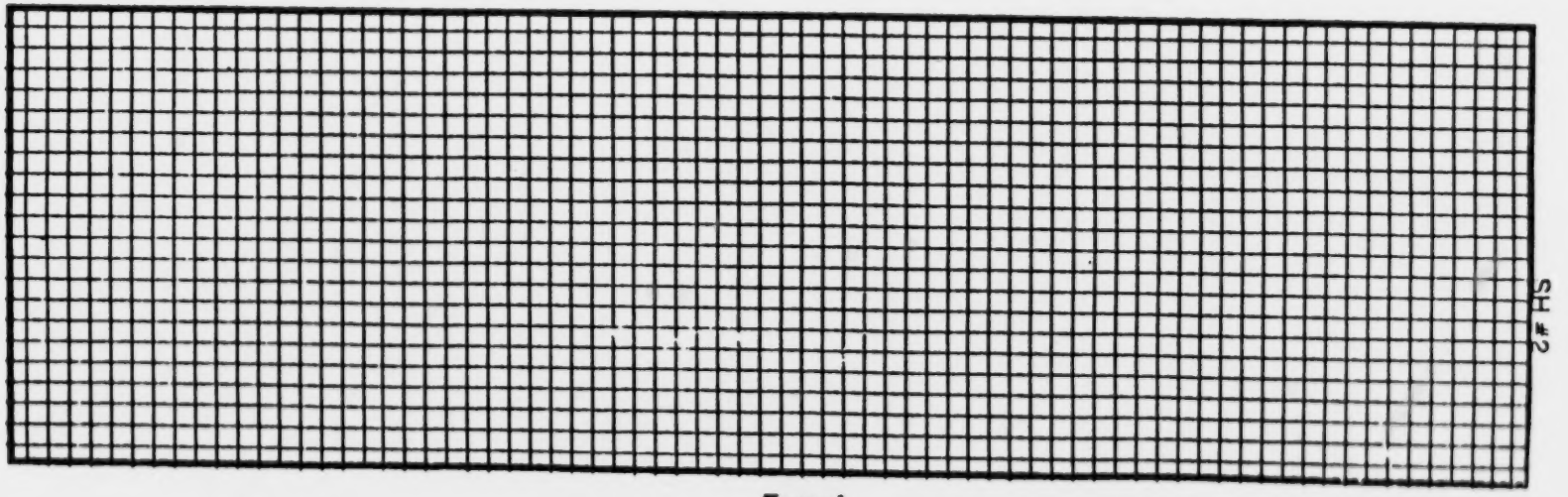
37

Final Sketch



Top

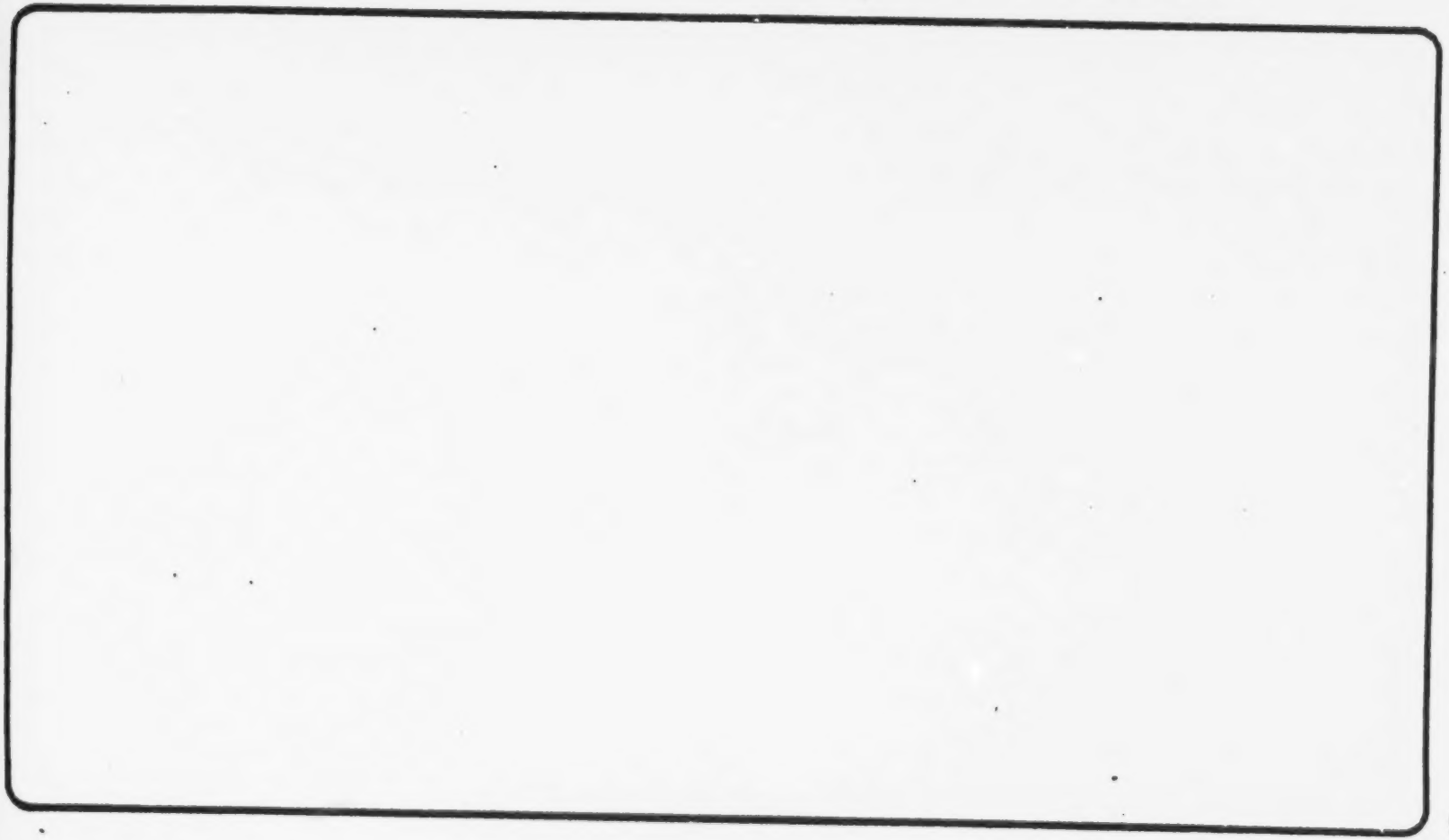
19-L



Front

SH #2

Wind Tunnel Analysis Sheet



Description

SH #3

41

Activity Analysis

Directions: Circle the best answer or fill in the blank with the correct answer.

1. Aerodynamics is the effect of air flow and the forces involved when an object moves _____ air or when air _____ past an object.

2. Vehicles that travel less than the speed of sound should have a _____ shape

   A. round
   B. blunt
   C. teardrop
   D. square

3. What are eddie currents?

   _____

   _____

   _____

4. Explain how a wind tunnel can be used to test aerodynamic design.

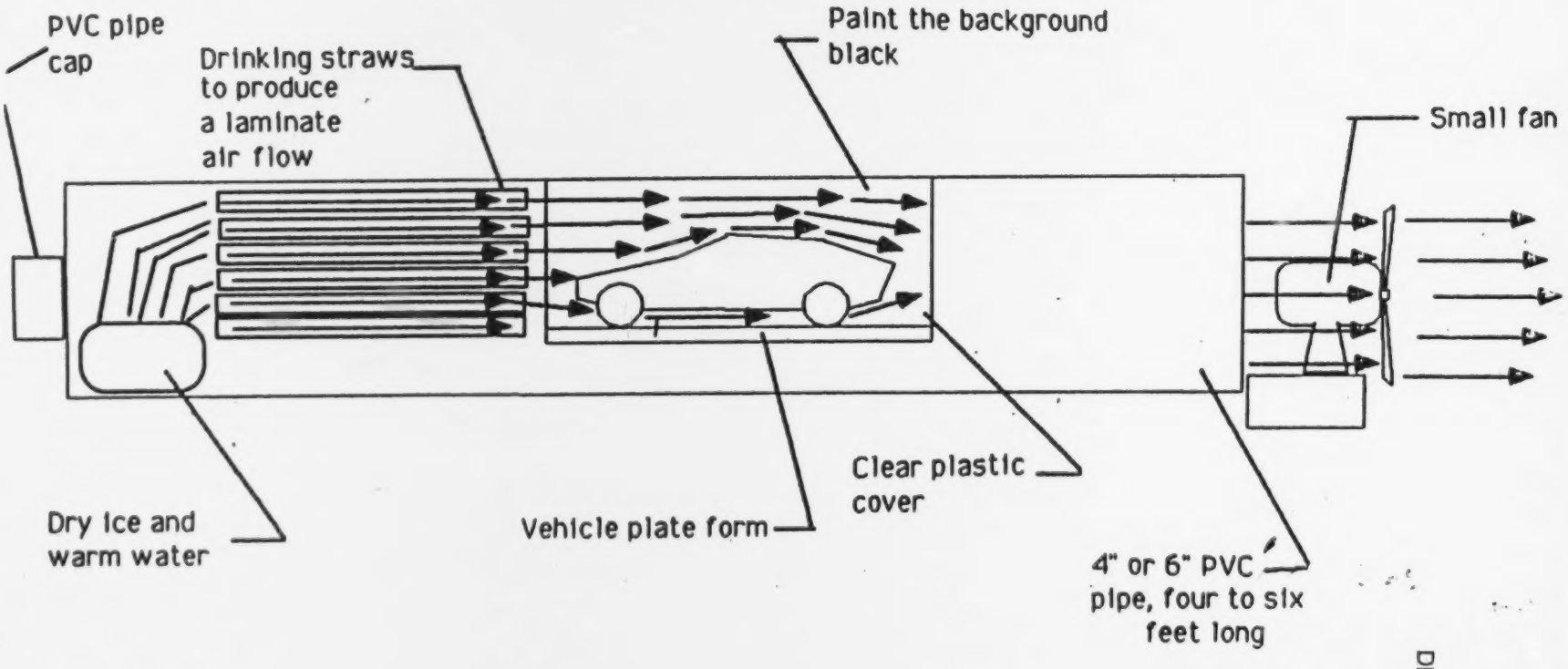
   _____

   _____

   _____

   _____

Wind Tunnel


PVC pipe cap
Drinking straws to produce a laminate air flow
Paint the background black
Small fan
Dry ice and warm water
Vehicle plate form
Clear plastic cover
4" or 6" PVC pipe, four to six feet long

DR #1

CALCULATING DRAG COEFFICIENT

Introduction

As an automobile travels down the highway, it must push through the air. The force pushing backwards against the automobile is called drag. Automobiles use up to 65 percent of their fuel pushing through the air. In order to make automobiles more fuel efficient, designers must find ways to reduce drag.

This Technology Education Activity is intended to complement a vehicle design activity. A design activity where students design and build an aerodynamic vehicle. This activity will allow students to test their designs by showing them how to calculate the drag coefficient. Through this experience, students will be able to identify the drag reducing feature on today's automobiles.

Materials and Supplies

Each group of two or three students will need:

* Access to a wind tunnel (Dr #1)
* test vehicle
* calculator
* Wind speed indicator (can be found in the weather section of most science-related supply catalogs)

Problem Statement

You are a member of a design engineering team in the research and development department of the Magnum Automotive Company. Your team is in charge of calculating the drag coefficient for a new automotive design. To increase fuel efficiency, the new design must have minimal drag.

Activity Procedures

1. Each group of two or three should obtain the materials needed to complete the activity.

2. To calculate a vehicle's drag coefficient, use the following formula:

$$\text{Drag Coefficient} = \frac{\text{Drag force on the vehicle}}{\text{Speed of the vehicle}}$$

3. To determine the speed of the vehicle, turn on the wind tunnel blower. Then, place the hand-held wind speed indicator inside the wind tunnel with the back of the indicator facing the blower. Once the ball in the tube has stabilized, record the reading, then turn off the blower.

   What is the wind speed inside the wind tunnel? _____ The wind speed represents the speed of the vehicle.

4. To determine the drag force on the vehicle, place the vehicle in the wind tunnel and attach the vehicle to the spring scale (see DR #1). Then, turn on the blower. Once the blower has reached full power and the vehicle has stabilized, record the reading on the spring scale, then turn the blower off.

   What is the reading on the spring scale? _____ The reading represents the drag force on the vehicle.

5. The next step is to calculate the drag coefficient. To do this, divide the drag force on the vehicle by the speed of the vehicle. Follow the steps listed below.

$$\text{Drag Coefficient} = \frac{\text{Drag force on the vehicle}}{\text{Speed of the vehicle}}$$

$$\text{Drag Coefficient} = \_\_\_\_\_$$

$$\text{Drag Coefficient} = \_\_\_\_\_$$

Activity Analysis

1. Explain why lowering a vehicle's drag is important.

_____

_____

_____

_____

2. Describe how the vehicle used in this activity can be modified to improve its drag coefficiency.

_____

_____

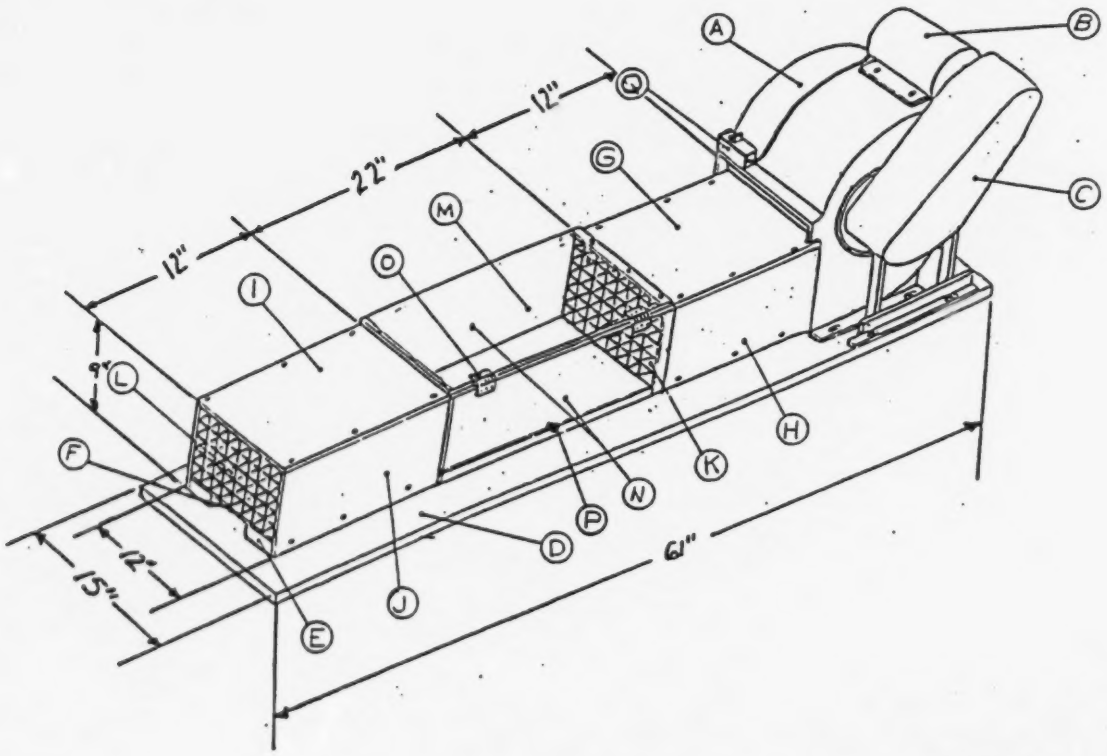
_____

_____

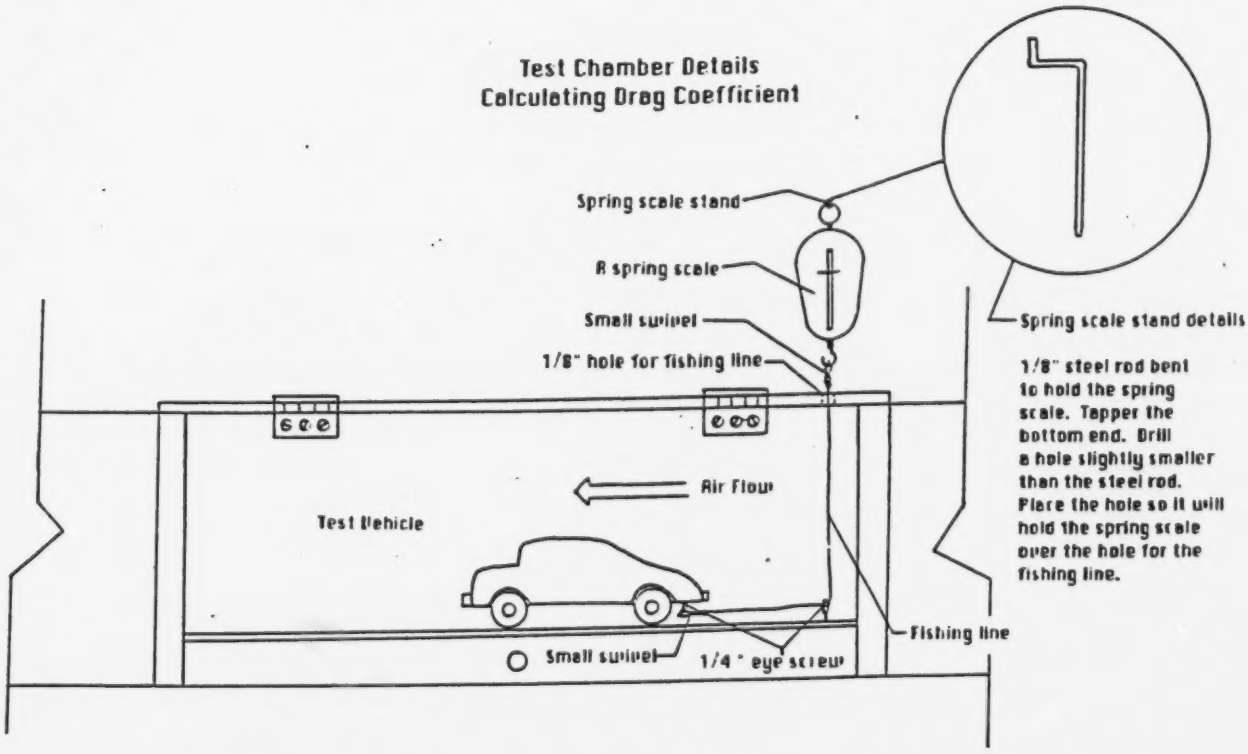
3. Identify various drag reduction features found on today's automobiles.

Wind Tunnel

DR #1



Test Chamber Details
Calculating Drag Coefficient


Spring scale stand
R spring scale
Small swivel
1/8" hole for fishing line
Air Flow
Test Vehicle
Small swivel
1/4 " eye screw
Fishing line
Spring scale stand details
1/8" steel rod bent to hold the spring scale. Tapper the bottom end. Drill a hole slightly smaller than the steel rod. Place the hole so it will hold the spring scale over the hole for the fishing line.

BILL OF MATERIALS FOR A FURNACE BLOWER WIND TUNNEL

PART		DESCRIPTION & PROCEDURES
A	*	Furnace blower - NOTE: **The actual construction of your wind tunnel may vary from the process described below due to the various styles of furnace blowers available.**
B	*	Furnace blower motor
C	*	Sheet metal cover - to protect students from moving parts. The cover should be made to fit over furnace blower pulley system. The size and shape will vary depending on the style of the blower.
D	*	Base - made of a piece of plywood or particle board, 3/4" x 15" x 61"
E		Two 2" x 4" x 47" bottom spacers and supports. The blower used in the drawing has a 1 1/2" space below the blower opening. Two spacers were needed to force the airflow directly onto the test vehicles in the tunnel. Procedures for constructing the bottom of the wind tunnel: - Plane down each board so a 1/4" piece of masonite can set on top of the bottom supports and line up with bottom edge of the blower opening. - Line up each board to fit in the space below the opening. Adjust the boards so they are parallel to each other. - The distance from the outside edge of the board to the outside edge of the other board should be approximately 10 1/2". - Using wood screws, fasten the two boards to the base.
F	*	Wind tunnel floor - cut a piece of 1/4" masonite 10 1/2" wide x 47" long. Place the masonite on the top of the 2 x 4 supports and fasten it into place.
G	*	Front section top - 1/4" piece of masonite, cut to 12" x 12"
H	*	Front section sides - 2 pieces of plywood or particle board, cut to 8 3/4" x 12" Locate and fasten parts G and H as shown in DR #1.
I	*	End section top - 1/4" piece of masonite, cut to 12" x 12"
J	*	End section sides - 2 pieces of 3/4" plywood or particle board, cut to 8 3/4" x 12". Locate and fasten parts I and J as shown in DR #1. This should leave approximately 22" for the test compartment area.
K	*	Front air flow inserts - 1" x 1" squares made out of poster board to fit the opening - NOTE: Paper towel tubes can also be used as the air flow inserts.
L	*	End air flow inserts - 1" x 1" squares made out of poster board to fit the opening - NOTE: Paper towel tubes can also be used as the air flow inserts.
M	*	Test chamber top - 1/4" Plexiglass cut to 12" x 24" NOTE: Make the Plexiglass top 2" bigger than the test chamber opening. In order to be able to fasten it to the end section, drill pilot holes in the Plexiglass and fasten it to the top of the wind tunnel.
N	*	Test chamber sides - Two pieces of 1/4" Plexiglass cut to 9" x 24". Drill pilot holes in one piece of Plexiglass and fasten to the back side of the wind tunnel. This side will be used for viewing only. The front will be hinged so the test vehicles can be taken in and out. To keep the test chamber opening closed, attach a Velcro strip around the edge.
O	*	Hinges for test chamber door
P	*	Cabinet door knob
Q	*	Single pole/single throw switch to control the motor

MASS TRANSPORTATION

Introduction

The purpose of this lab activity is to allow students to experience the capabilities and problems mass transportation has to offer. Students will explore routing, time schedules, and efficiency of mass transportation means as opposed to personal vehicles as a means of moving people. The environmental impact of various means of moving people are stressed.

Materials and Supplies

This activity can be done as a small group activity (4-5 students). The following materials are needed for each group.

* 1 programmable crawler robot (e.g., WOA, NARVIS)
* 1 large map layout of a mock community (based on DR #1). NOTE: The scale of the layout may vary depending on the size and freedom of movement of the crawler robot.
* 1 calculator

NOTE:
Several crawler robots are available, (e.g., WOA, NARVIS) some are in kit form and could be student-assembled. A line tracer could be substituted for a programmable robot.

Problem Statement

A community consisting of three residential areas, a large shopping mall, an industrial park, and an office complex has a need for a mass transportation system that will most efficiently get people to and from their places of employment. The community layout shows population distribution, necessary destinations, time schedules, schedule and routing sequence to most efficiently meet the needs of this community for a twenty-four hour period. Calculate riders on each route, the cost per rider per mile on each route, and the miles traveled per gallon of fuel per rider. Compare these figures to the cost and miles per gallon per rider for a single passenger vehicle and an auto car pool for four riders.

Parameters:

Bus capacity: 60 riders maximum
Fuel economy: Bus - 3 miles per gallon
Single passenger auto - 18 mpg
4 passenger car pool - 19 mpg
Fuel costs: $1.25 per gallon

Activity Procedure

1. Each group of three or four should obtain the needed materials. Make sure you understand how to properly operate the robot. In this activity the robot represents a 60 passenger bus.

2. Reread the problem statement carefully. Study the mock community and mock community data sheet (SH #1). Based on the figures given on the mock community layout, calculate the number of "bus" runs needed and the necessary routes for each run in order to get all residents to work and home on time.

3. Record the number of people that will ride the bus on each bus run. You might want to devise a system of identifying individual bus runs. Also calculate the mileage of each route and record.

Bus Route _____	No. of Passengers _____	Mileage _____
Bus Route _____	No. of Passengers _____	Mileage _____
Bus Route _____	No. of Passengers _____	Mileage _____
Bus Route _____	No. of Passengers _____	Mileage _____
Bus Route _____	No. of Passengers _____	Mileage _____
Bus Route _____	No. of Passengers _____	Mileage _____

4. Program the "bus" for each route and allow it to follow the route on the community layout. Try to determine if the routes traveled are the most efficient. If not, reprogram the robot to travel a new route.

5. Using the following formulas, calculate the cost per rider per mile for each bus route and the miles per gallon per rider for each route.

   (Cost of fuel ÷ MPG) ÷ no. of riders = cost per rider per mile)

   Cost/rider/mile = _____ Miles/gal/rider = _____

   MPG ÷ no. of riders = miles per gallon per rider

6. Now, calculate the distance from each residential area to each employment complex by the shortest route.

   Glenwood Park to the Mall ___ to Industrial Park ___ to Office Complex ___

   Berkshire to the Mall ___ to Industrial Park ___ to Office Complex ___

   Indian Valley to the Mall ___ to Industrial Park ___ to Office Complex ___

7. Now, using formulas from #5, calculate the cost per rider per mile and miles per gallon per rider for a single passenger automobile and a four passenger car pool vehicle.

Single Passenger	4 Passengers
Cost/Rider/Mile = _____	Cost/Rider/Mile = _____
Miles/Gal/Rider = _____	Miles/Gal/Rider = _____

8. Based on calculations from #5 and #7, which mode of transportation is most efficient if the distance traveled is equal?

9. Using mileage figures from #3 and #6 and the formula given, calculate the actual gallons of fuel used per person for each bus route and for a single passenger vehicle and a four passenger vehicle.

Mileage ÷ miles/gal/rider = gallons/rider

Bus Route _____	Gallons/Rider _____
Bus Route _____	Gallons/Rider _____
Bus Route _____	Gallons/Rider _____
Bus Route _____	Gallons/Rider _____
Bus Route _____	Gallons/Rider _____
Single passenger___	Gallons/Rider _____
4 passengers _____	Gallons/Rider _____

Activity Analysis

1. Why do many people prefer personal transportation to mass transportation?

_____

_____

_____

2. Is mass transportation more efficient than personal transportation?

_____

_____

_____

3. In virtually all cases, mass transportation is _____ cost and fuel efficient than personal transportation.

a. less
b. more
c. equally

MOCK COMMUNITY DATA SHEET

Scale: 1/4 inch = 1/2 mile NOTE: The scale of the layout may vary depending on the size and freedom of movement of the crawler robot.

Office Complex: Business hours - 8:00 am to 5:00 pm

Industrial Park: 24 hour shifts

7:00 am to 3:00 pm
3:00 pm to 11:00 pm
11:00 pm to 7:00 am

Shopping Mall: Business hours - 10:00 am to 9:00 pm

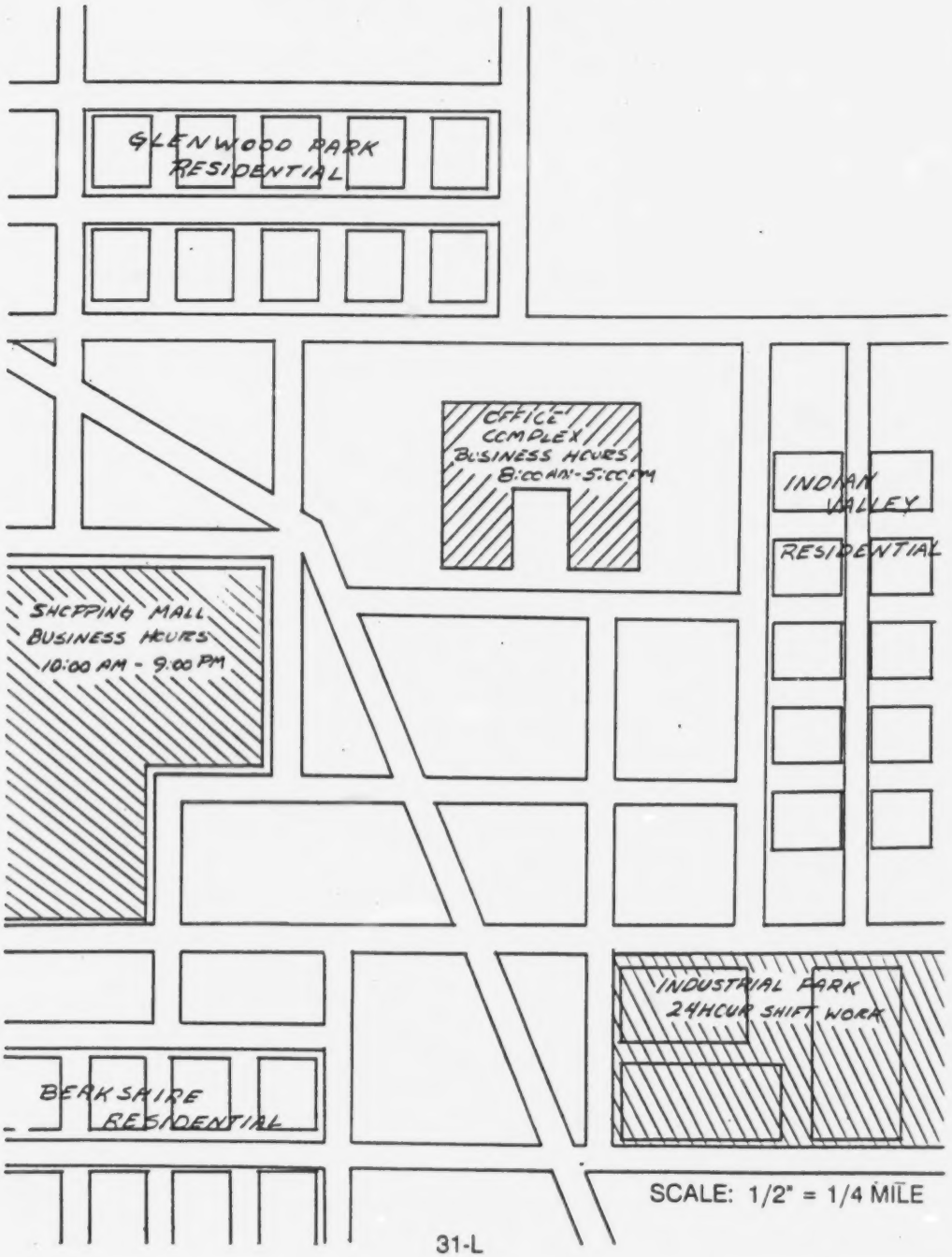
Residential Population and Employment Distribution

Glenwood Park - 75 working residents
- 10 work in the mall
- 20 work in the office complex
- 45 work in the industrial park
  - 15 @ 7-3 shift
  - 12 @ 3-11 shift
  - 18 @ 11-7 shift

Indian Valley - 60 working residents
- 10 work in the mall
- 15 work in the office complex
- 35 work in the industrial park
  - 20 @ 7-3 shift
  - 6 @ 3-11 shift
  - 9 @ 11-7 shift

Berkshire - 35 working residents
- 5 work in the mall
- 23 work in the office complex
- 7 work in the industrial park
  - 4 @ 7-3 shift
  - 3 @ 3-11 shift

SAMPLE MOCK COMMUNITY


GLENWOOD PARK RESIDENTIAL
OFFICE COMPLEX BUSINESS HOURS 8:00 AM - 5:00 PM
INDIAN VALLEY RESIDENTIAL
SHOPPING MALL BUSINESS HOURS 10:00 AM - 9:00 PM
INDUSTRIAL PARK 24 HOUR SHIFT WORK
BERKSHIRE RESIDENTIAL
SCALE: 1/2" = 1/4 MILE
31-L

MATERIALS-HANDLING TRANSPORTATION TECHNOLOGY

MATERIALS-HANDLING SYSTEMS

Suggested Learning Objectives

Upon completion of the material-handling unit, students will be able to:

A. Define and properly use material-handling **terminology** like route, aggregation, teach pendant, distribution, controller, coordinate, and actuator.

B. Identify basic **applications** for materials handling systems like distributing oil and natural gas, moving materials and products through manufacturing facilities, sorting mail, loading and unloading vehicles.

C. Describe the societal and environmental **impacts** associated with material-handling activities like improved efficiency, interference with wildlife migratory patterns, visual pollution, land utilization, and displaced workers. SC2

D. Describe the major **processes** used for transporting and handling goods like loading, unloading, storing, packing, protecting, shipping, conveying, palletizing, and lifting.

E. Describe the basic human, material, natural, informational, financial, and technological **resources** associated with material-handling processes and enterprises.

F. Identify, describe, and evaluate **career** opportunities related to material-handling (e.g., industrial engineer, robot technician, fork-lift operator) based on their interests, talents, and career expectations.

G. Identify potential **safety** hazards, establish guidelines for safe behavior, and adhere to common safety practices when around or participating in material-handling activities. PH3

H. Describe the major milestones in the **history** and evolution of material-handling technology including the invention of the elevator, the introduction of fork-lifts, and the construction of the Alaskan pipeline. SS2

I. Describe the advantages, disadvantages and potential applications for various materials handling systems like pipelines, pneumatic tubes, automated guided vehicles, robotics, and automated storage and retrieval systems. SC2

J. Discriminate between fixed path and variable path materials- handling systems.

K. Design, build, test, and present a materials-handling system that addresses a material-handling problem based on environmental, financial, material, safety, and energy considerations.

L. Forecast the implications of automated materials-handling systems on things like safety, labor patterns, flexibility, efficiency, and worker qualifications. SC2

M. Select the tools, materials, and processes needed to address a given material-handling problem.

N. Determine the optimum means of transporting a given object within a facility based on transportation, process, cost, time, energy, and safety considerations.

O. Describe the basic payload, guidance, propulsion, control, and support systems for a given material handling system.

Suggested Learning Activities

1. Discuss how materials like petroleum and natural gas can be transported by means of pipeline technology. Using materials like a windshield washer pump, rubber hose, aquarium valves, T-fittings, and three containers, have a small group of students design, build, and test a model pipeline for a fictitious petroleum company that needs to move oil from a well to several refineries. Possible design considerations could include things like refinery capacity, terrain, animal migration patterns, distribution points along the pipeline and pipeline length. Have students analyze the advantages and disadvantages of pipeline technology versus other forms of transportation. Discuss the impact of pipeline technology on wildlife and the environment.

2. Introduce students to the concept of automated guided vehicles (AGV). Using materials like hobby motors, wheels, batteries, switches, wood, hardboard, and gears, have small groups of students design, build, and test an automated guided vehicle (AGV). When students have finished their AGV, place several numbered hardboard templates representing work cells in a flexible manufacturing system on the floor in a random order. Have each team write a program using simple English statements (pseudo code) describing the sequence of steps needed to navigate their AGV through the work cells. Have each team demonstrate their program to the rest of the class. Ask students to identify potential applications for AGV technology and describe the impact automated guided vehicles might have on employment, productivity, and competitiveness.

3. Discuss the various techniques used to move materials along a fixed path within a facility. Include things like chutes, elevators, augers, and conveyers (i.e., belt, roller, trolley, and bucket). Divide the class into teams and provide each team a problem statement. Possible problem statements could include things like moving components from one workstation to another, moving freshly painted parts through an oven, and moving products from one elevation to another. Using materials like motors, wood, PVC pipe, canvas, and rubber, have students design, build and test materials-handling systems. Design considerations should include things like speed, safety, accuracy, and dependability. Ask the students to discuss how fixed path materials-handling systems shape production processes and worker behavior.

4. Discuss the various techniques used to move palletized materials. Include things like hand trucks, carts, fork- lifts, hoists, and cranes. Divide the class into teams and provide each team a problem statement. Possible problem statements could feature tasks like moving a batch of components from one workstation to another, loading and

unloading a vehicle, and handling containers. Using materials like wheels, pulleys, and scrap material, have students design, build, and test functional or model variable path materials-handling systems. Ask students to compare and contract the resources and applications used in fixed versus variable path materials-handling systems.

5. Discuss the role of robotics as a fixed yet flexible material handling technology. Using materials and components like syringes, 1/8" plastic tubing, masonite, hobby motors, rubber bands, and switches, have small groups of students design, build, and test a simple pick and place robot that will move an assigned object from one location to another (e.g., washers, wooden blocks, ping pong balls). When students have finished their robots, have them write, test, and demonstrate a pseudo code program (English statements) describing the sequence of steps needed to move their assigned object. Have students explain how robotics free humans from dull, dirty, and dangerous types of work and how they extend human potential. Have students identify the impact of robotics on the qualifications needed to work in modern manufacturing companies.

6. Introduce students to the concept of teaching an industrial robot to perform a task. Discuss the various techniques used to teach industrial robots to perform tasks (e.g., teach pendant, walk through, programming). Using a computer simulated, table top, or mobile robot, have students teach a robot to perform a sequence of operations based on a problem. Potential problem statements could feature tasks like stacking objects, putting objects in a given order, placing objects in new locations upside down, follow a specific path, and/or place objects in containers. Ask students to compare the flexibility of robots to other forms of material handling technology. Discuss how industrial robots effect some company's ability to compete within the United States and world markets.

7. Explain how materials can be moved on a cushion of air, thus reducing friction and drag. Using materials like a 4 foot plywood disk, 6 mil plastic, a shop vacuum, and duct tape, have small groups of students design, build, and test an air bearing material handling device. During the testing process, have students take turns transporting each other on the air bearing. Ask students to determine the minimum pressure needed to lift the load that will move three bricks a distance of twenty feet. Have students identify and discuss the advantages, disadvantages, and potential application of air bearing devices.

8. Discuss the milestones in the history and evolution of materials-handling systems. Assign each student a historical event. Using library resources, have students gather information and develop an abstract describing the people, dates, places, and impacts associated with their assigned event. Encourage students to illustrate their abstracts. Post each abstract on a large timeline. Ask students to describe how given events influenced our culture and subsequent technological developments.

9. Discuss the career opportunities in materials-handling systems. Include occupations at the non-skilled, semi- skilled, skilled, technician, and professional levels in the discussion. Using library and guidance resources, have students gather information and present a short written or verbal report about an occupation related to materials- handling systems. Each report should include information about the educational requirements, working conditions, benefits, salary, and advancement potential related to the occupation. Ask students to evaluate the career based on their interests, talents, and career expectations.

ROBOTICS

Introduction

According to the Robotics Industries Association, "an industrial robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks." Simply stated, an industrial robot is a machine that can be programmed to perform an industrial task.

Industrial robots have three basic parts, a manipulator arm, a controller, and a power supply. The manipulator arm is the part that actually does the work. The manipulator arm, like a human arm, includes joints and an "end effector." The end effector acts like a human hand. It can have two or three gripper-like fingers that can pick up parts or a chuck (holder) for special tools.

The controller is the robot's brain and it is basically a computer. Programming a robot is called "teaching." One way to teach a robot to perform a given task for a technician to use a teach pendant to give instructions to the robot. While the robot is performing the task, each step it takes is being stored in the memory of the controller. Once the robot has been taught a task, it can repeat the task over and over again automatically.

The power supply provides the power for the manipulator arm. It can either be electric, hydraulic, or pneumatic. The power supply acts like the robot's heart and muscles. It provides the energy for pushing, pulling, turning, and lifting.

Typically, robots are used to perform tasks that are dull, dirty, and/or dangerous. Common applications for industrial robots include materials handling, tool operations (e.g., welding, drilling, cutting, painting, deburring, inspection), and assembly. Industrial robots typically increase production capability, improve product quality and lower production costs.

This Technology Education Activity will provide students with an opportunity to experience basic robotic concepts by designing, building, programming, and testing a simple pick and place robot.

Materials and Supplies

Each design team will need to be able to choose from a variety of:

* medical syringes varying in size from 5cc to 20 cc
* hardboard disks ranging in size from 2" to 6" in diameter
* rubber bands varying in size and strength
* scrap pine, sheet metal, and hardboard in various sizes and shapes
* dowel rods (mostly 1/4" diameter)
* fasteners (nails, screws, wire nuts, small nuts and bolts, etc.)

Each design team will need at least:

* 1 large hobby motor
* 4' of automotive vacuum or plumbing hose with an 1/8" internal diameter
* 4' of speaker wire
* 1 DPDT center-off toggle switch
* 1 6-volt battery
* 1 plywood platform 3/4' thick, 1' wide, and 2' long
* 1 widget made out of 1" wide, 1" thick, and 2" long scrap wood.

Problem Statement

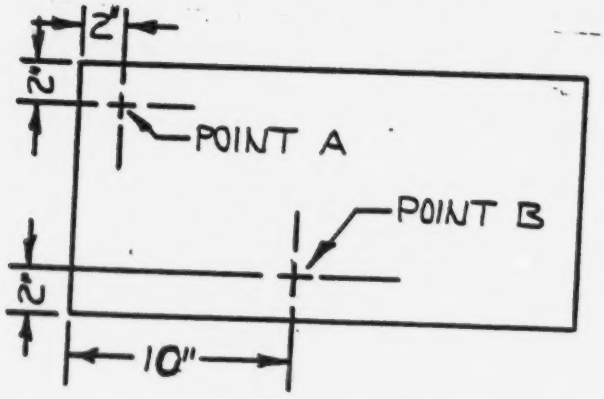
You are a designer at Acme Robotics, Ltd. Your firm has been asked to design a robotic material handling system for the Winkle Widget, Inc.

Winkle Widget, Incorporated makes (you guessed it) widgets. During the manufacturing process, widgets need to be moved from one conveyor system to another by hand. Moving the widgets by hand is boring and dangerous. The company has had to pay a lot of medical bills due to injuries caused by moving widgets. Management feels using a robot to move widgets will free personnel for more important work, reduce accidents, and improve productivity.

Your department head has decided to put together several design teams. Each design team will develop and present a proposal for solving Winkle Widget's material handling problem. Each proposal will be in the form of a working model robot. The design team that presents the best proposal will receive the contract.

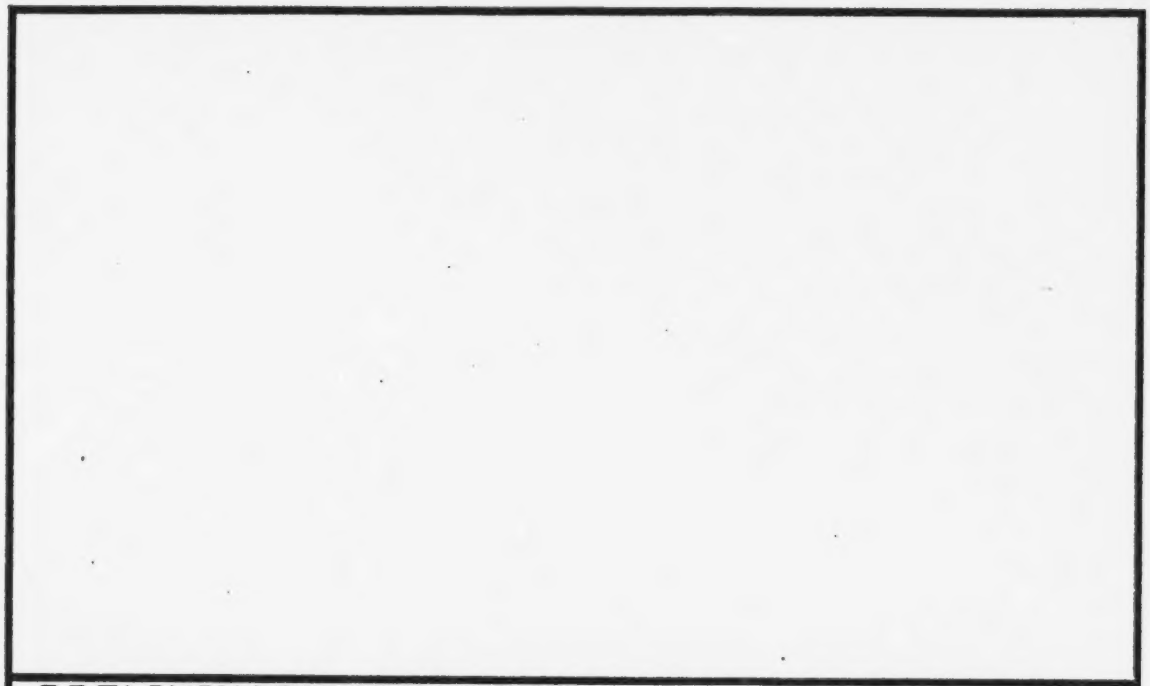
Activity Procedure

1. Discuss with your team members various ways you could transport your widget from point A to point B using the materials available. Try not to evaluate each idea right away. The most important thing is to develop as many ideas as possible and to record each idea in the form of a sketch.
2. After you have developed several designs, evaluate each design carefully, select the best design, and/or combine several good ideas into one final design.
3. Next, lay out points A and B on your platform according to dimensions illustrated on the plan below.

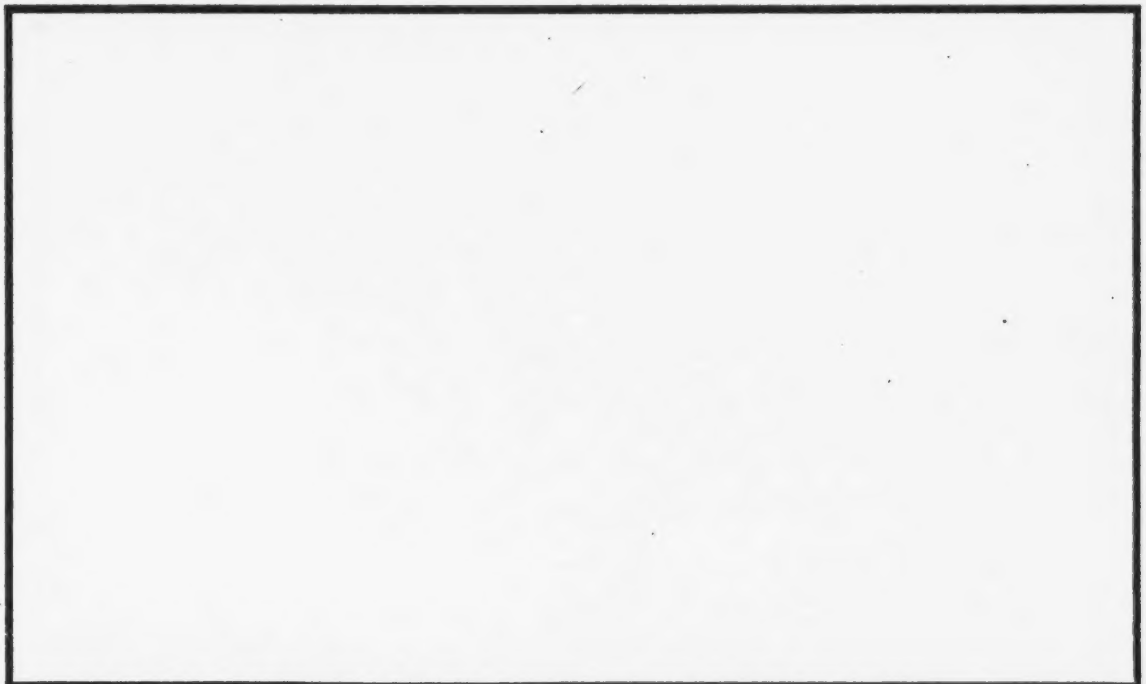


5-M

4. Using the materials provided, locate and build a working model robot on the platform that can move your widget from point A to point B.
5. When you have finished building and testing your model robot, prepare your proposal presentation. Your presentation should include:
   A. an introduction that includes a brief statement of the problem and how your design team approached the problem.
   B. an explanation of how your robot works (include a discussion of things like special linkages, mechanism, fluid power systems and/or electrical systems).
   C. a demonstration of how your robot works.



PRELIMINARY IDEAS FOR WINKLE WIDGET, INC.
ACME ROBOTICS, LTD.



FINAL DESIGN FOR WINKLE WIDGET, INC.
ACME ROBOTICS, LTD.

BASIC DIMENSIONS:
1" WIDE × 1" DEEP × 2" HIGH

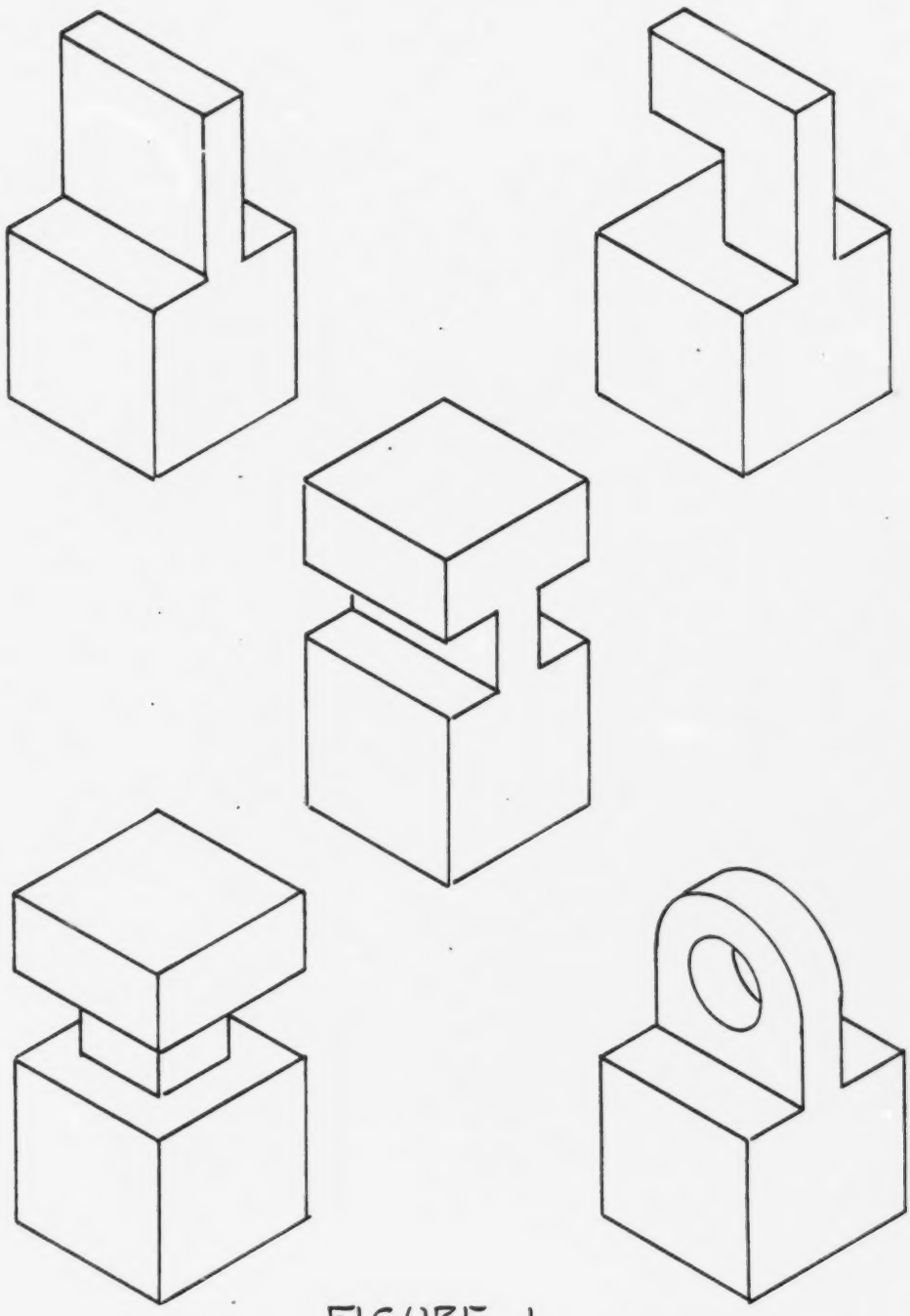


FIGURE 1
EXAMPLE WIDGETS

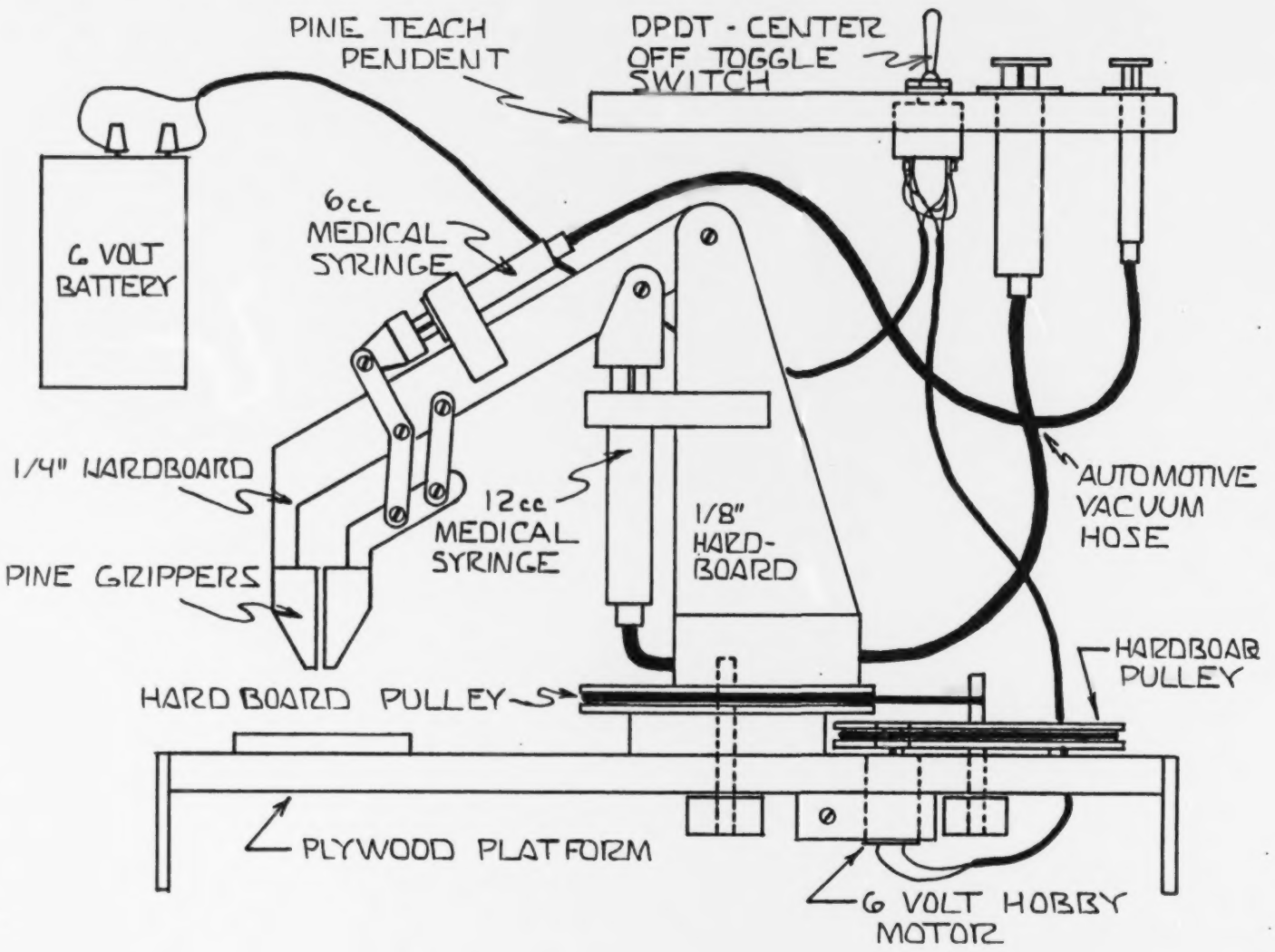


FIGURE 2
EXAMPLE ROBOT

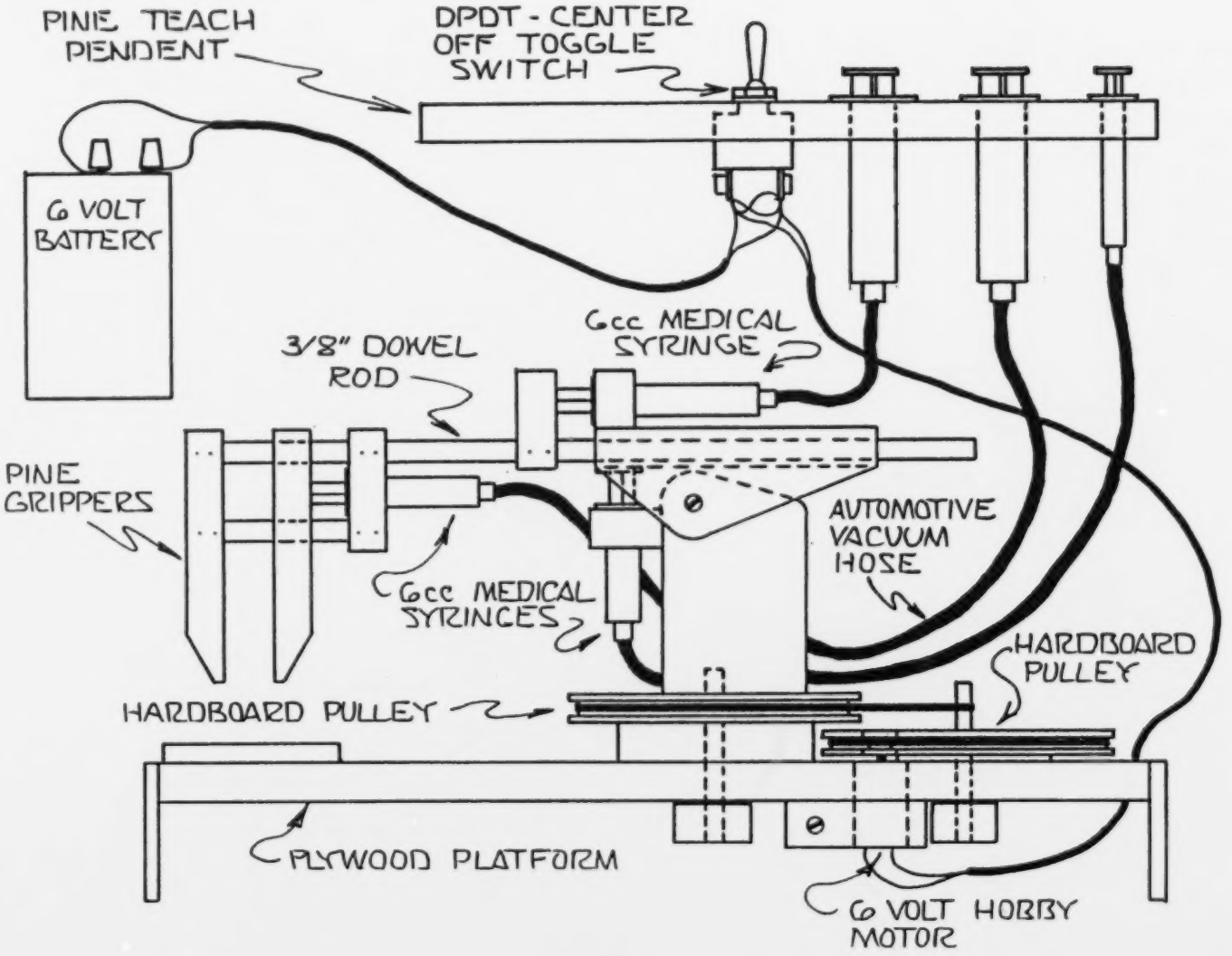


FIGURE 3
EXAMPLE ROBOT

PSEUDO CODE
(PROGRAMMING A ROBOT)

Introduction

A robot must be programmed with a series of instructions before it can complete a task. The program directs the various servo-motors and/or fluid power devices to move the robot and its various parts. The instructions can swing the arm, twist its wrist, manipulate the end effector, or direct a number of other actions. Programming can be done in three basic ways: (1) on-line programming, (2) off-line programming, and (3) computer graphic interface.

On-line programming is the simplest way to send instruction to the robot. An operator moves the robot through all the moves needed to perform a task. A memory unit of the robot records each action exactly as it was performed. Then the robot can automatically repeat the task over and over.

Off-Line programming uses one of several computer languages to program the robot. These languages direct the robot to perform its actions. Common off-line programming languages include AL (Stanford Artificial Intelligence Laboratory), AML or A Manufacturing Language (IBM), HELP (General Electric), LARS (Jet Propulsion Laboratory), MCL (McDonnell Douglas), RAIL (Automatix), RPL (SRI International), and VAL (Unimation, Inc.).

Computer graphic systems are being used to complement off-line programming. They allow the programmer to design work stations, simulate robotic movements, and evaluate robot programs all without leaving the computer screen.

This Technology Education Activity is designed to allow students to operate a robot from a prepared program, write a simple program simulating on-line programming, and instruct a robot to complete an assigned task. NOTE: This activity can be used along with the Designing Industrial Robot activity which is also contained in this packet.

Materials and Supplies

Equip each group of two or three students with:

* A commercial or constructed manually controlled robot
* Either a wood widget or metal objects such as washers or nuts depending on the type of robot you use.
* Robot Program Worksheet

Problem Statement

Your company is automating several operations. You have been assigned to write programs that will cause the robot to perform the tasks, tasks such as:

** move two widgets from point (A) to point (B).
** move two widgets from point (A) to two different fixtures at point (B).
** move three widgets from point (A) and stack them one top of each other at point (B).
** move five 1/2" washers from point (A) and place them in two different containers at point (B).
** move three 1/2" hex nuts from point (A) and stack them on a dowel at point (B).

Activity Procedure

1. After receiving a task, obtain the needed materials from your intructor:

2. Assign one member of the group to each of the following robot controls:

   (Note: Control assignments may vary according to the type of robot you are using.)

   Electromagnet Robot

   Controller #1 - Pivot control (making the robot move left and right).

   Controller #2 - Arm control and end effector control (making the robot's arm move in and out and turn on and off the electromagnet)

   Program recorder - List the moves and operations in a step-by-step order.

   or

   Gripper Robot

   Controller #1 - Pivot control (making the robot move left and right.

   Controller #2 - Arm control and end effector control (making the robot's arm move in and out and open and close the gripper).

   Program recorder - List the moves and operations in a step-by-step order. He/she will then act as the computer (processor and output device) by reading the program supplied by another group.

3. As a group, experiment with the movements of the robot.
4. Place the assigned object at point (A).

5. Write a pseudo code program. Using simple English statements, your program will list all the steps required to move your widget from point A to point B with your robot. Begin by placing your robot in a starting position. Record this position in your program by calling it "Home." Next, complete one step toward moving your robot to point A. Using words like goto, move to, rotate, or turn, record this operation on the robot program sheet. Complete the next step and record it. Continue this process until you have created a list of instructions that anyone could use to move your widget from point A to point B and to return your robot to its "Home" position.

   Sample Pseudocode Program

   10 home position
   20 rotate clockwise to point A
   30 open grippers
   40 lower arm one inch
   40 grip the object
   50 lift arm one inch
   60 rotate counter-clockwise to point B
   70 lower arm one inch
   80 open the grippers
   90 lift arm one inch
   100 close the grippers
   110 rotate clockwise to home position
   120 repeat the cycle

6. Test the program by having the person who is the program recorder read the pseudo-code program. As the program is read, each of the group members should operate their assigned control to perform the program.
7. Modify the pseudo-code program as needed.
8. As other groups finish, exchange programs (and robots if necessary) and test their program on the robot.
9. Note any errors discovered in the program.
10. Return the program to the originating group.

Activity Analysis

Based on the experience gained during this activity:

1. How could the programming process be improved?

   _____
   _____
   _____

2. What impact could programming have on the qualifications of future workers who want to be employed in modern manufacturing companies?

   _____
   _____
   _____

ROBOT PROGRAM SHEET

CONTROLLER NUMBER	COMMAND

AUTOMATED GUIDED VEHICLE

From TNT (April, 1988)

Introduction

Automated guided vehicles (AGV's) are becoming a popular means of transporting materials within a facility. They are being used to distribute mail in large offices, carry parts in manufacturing plants, and moving products in warehouses. They are basically driverless carts that follow fixed or flexible routes. Fixed route systems often use wires or chemically treated strips on the floor to guide AGV's. Flexible route systems use onboard sonar, computer, laser, infrared, and/or gyroscope-based navigation systems to guide AGV's.

Materials and Equipment

* 2 5" x 7" pieces of 1/4" hardboard
* 2 2 3/4" diameter pieces of 1/4" hardboard
* 2 3/4" x 1 1/4" x 1 1/2" pieces of wood
* 2 3/4" x 1 1/2" x 2: pieces of wood
* 1 3/8" x 3/4" x 2 1/2" piece of wood
* 3 1/4" x 2 carriage screws
* 6 1/4 nuts

* 2 1.5 to 3 volt hobby motors (For better control, try using hobby motors with gear reduction systems that can be connected directly to the wheels.)
* 2 small rubber wheels for HO scale slot car
* 1 battery holder
* 1 1.5 battery (Depending on your motors, you may need to use two 1.5 volt batteries in series.)
* 1 5' length of 6 conductor cable
* 2 DPDT center off toggle switches
* Miscellaneous screws, washers, and nails

Activity Procedure

1. Obtain the materials and parts listed above. Using a hole saw or fly cutter, make the wheels out of hardboard.
2. Using the illustrations as guides, (DR #1) cut out and drill the chassis, motor mounts, and axle mounts, and teach pendant.
3. Glue the axle mounts to the chassis and fasten the motor mounts so they can be adjusted back and forth. Install the axles, wheels, battery holder, and runner as illustrated. Mount the toggle switches to the teach pendant.
4. Fasten rubber wheels to the motor output shafts. Wrap narrow strips of masking tape around the motors until they fit snugly in the motor mounts.
5. Using the schematic as a guide, make the electrical connection needed to control the motors from the teach pendant switches with the six conductor cable.
6. When the AGV is finished, adjust the motors so they turn the wheels. Both pairs of motors and wheels should move as freely as possible without slippage.

7. Explain how some flexible route AGV's are programmed by guiding them through a sequence of movements from a teach pendant. Divide the class into groups of 2 to 3 students and have each group randomly place several numbered hardboard squares on the floor. Explain that each hardboard square represents a work station in a flexible manufacturing facility. Have each group write a program using simple English statements (pseudo code) while guiding their model AGV from one work station to the next. When they have finished, have each group exchange work station layouts and programs with another group. Using a program developed by their peers, have each group navigate their AGV through the sequence of work stations.

Sample Pseudo Code Program:

```
10   HOME
20   FORWARD 8 INCHES
30   RIGHT 45 DEGREES
40   FORWARD 6 INCHES
50   LEFT 45 DEGREES
60   FORWARD 4 INCHES
70   PICK UP STOCK
     ETC.
```

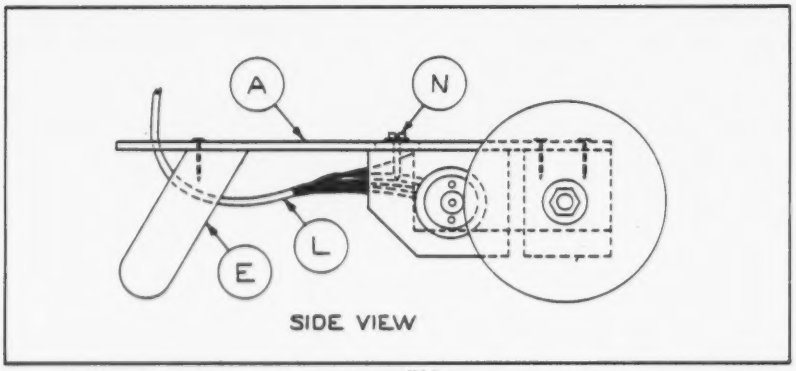
Activity Analysis

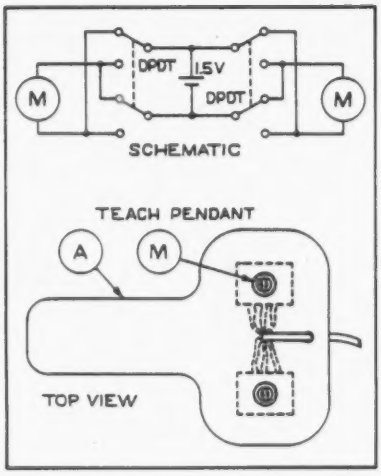
Discuss the advantages of using AGVs in a manufacturing facility.

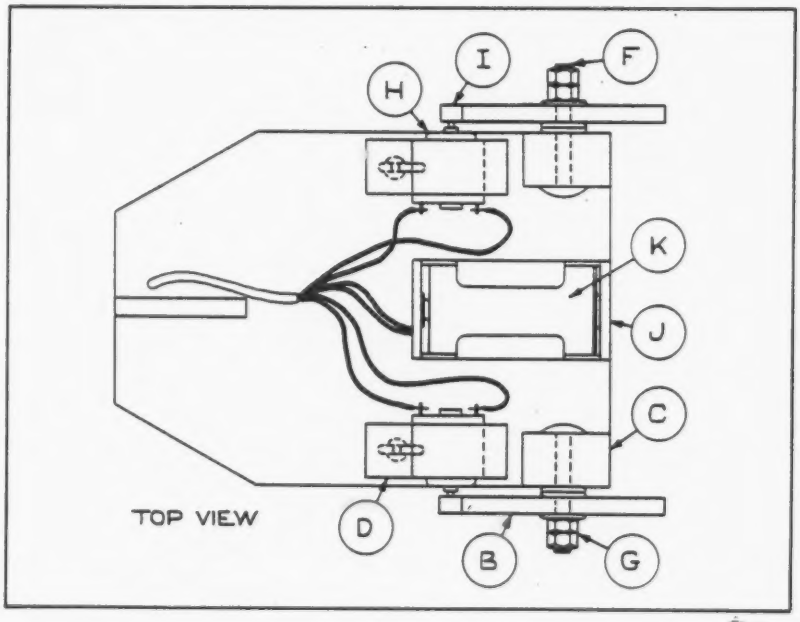
_____

_____

_____


A
N
L
E
SIDE VIEW


DPDT
1.5V
DPDT
M
M
SCHEMATIC
TEACH PENDANT
A
M
TOP VIEW


I
F
H
K
J
C
TOP VIEW
D
B
G

17-M

GUIDING TRANSPORTATION VEHICLES
AUTOMATED GUIDED VEHICLE

Introduction

Materials-handling systems, like automated guided vehicles (AGVs), are becoming a popular way to move a variety of materials and supplies throughout a facility. AGVs use a computer to provide information to the vehicle. The computer supplies the information about the vehicle's location and speed. Some AGVs follow wire or chemically treated strips installed in the floor. Other AGVs use onboard computers, lasers, sensors, and gyroscopes to guide the system. AGVs have been used to move products in a manufacturing plant, deliver mail in an office, and transport materials around a warehouse.

This Technology Education Activity will provide students the opportunity to use a mobile programmable robot to simulate how automated guided vehicles can be used in a materials-handling system.

Materials and Supplies

Each group will need the following materials:

* One mobile programmable robot (e.g., WOA, NARVIS)
* Access to a scale model of a plant layout for a given product. (For this activity, a memo pad holder will be used.) (DR #1)
* Flow process charts for the given product (SH #1)
* Plant layout showing the proposed materials-handling routes (optional). (DR #2)

Problem Statement

You are a member of the engineering department for Memo,Incorporated. Management has recently decided to automate the plant's materials-handling systems. Because of the facility layout, the plant has been divided into two separate routes. Your division has been assigned the task of programming an automated guided vehicle (AGV) for one of the materials-handling systems routes (your instructor will assign the route).

Activity Procedures

1. Each group should obtain the materials necessary to complete the activity.
2. As a group, study the flow process chart and scale model.
3. Using the mobile programmable robot, teach the robot the desired route.
4. Once your team has programmed the AGV, test it using the scale model.
5. If the AGV does not complete the route as planned, make necessary changes or modifications.

Activity Analysis

Based on the experience gained by conducting this activity:

1. What are the advantages of using AGVs in a manufacturing facility?

_____

_____

_____

2. What are the disadvantages of using AGVs in a manufacturing facility?

_____

_____

_____

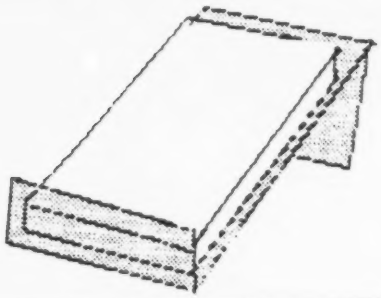
3. Besides manufacturing plants, where can AGVs be used as potential materials-handling systems?

_____

_____

_____

FLOW PROCESS CHART FOR MEMO HOLDER



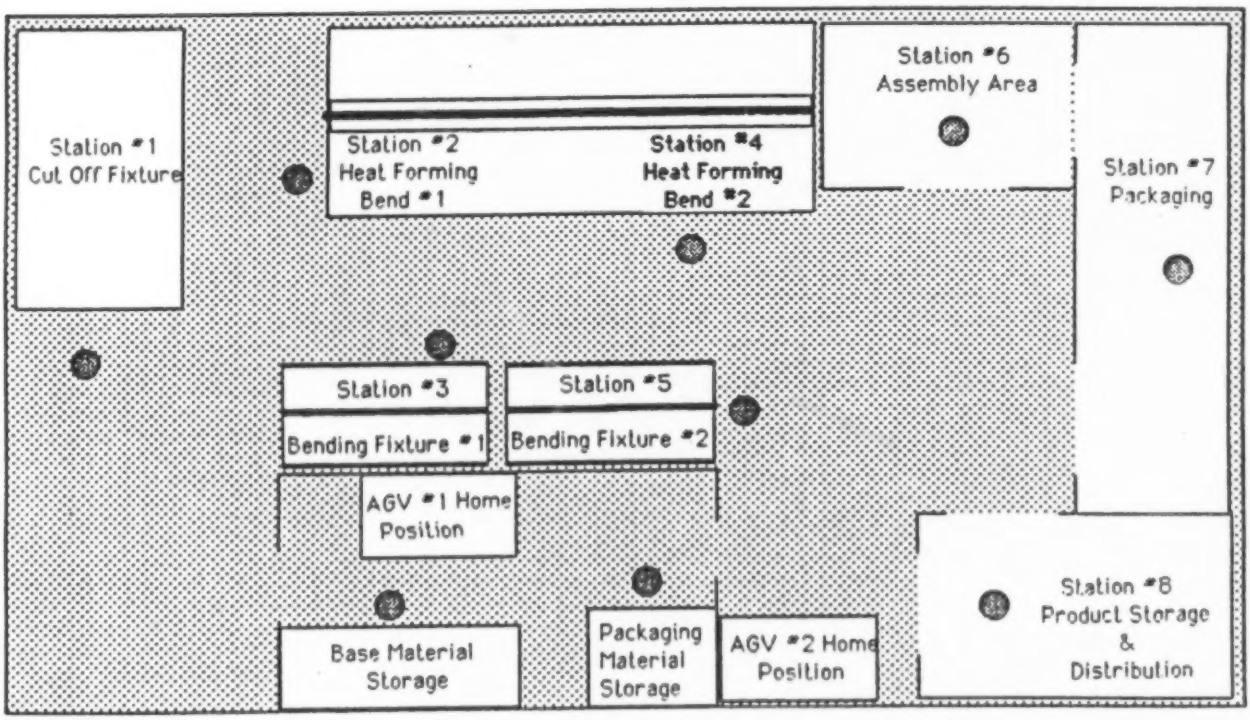
PROCESS SYMBOLS AND NO. USED	○ OPERATIONS 5	□ INSPECTIONS 0	⇨ TRANSPORTATIONS 7	D DELAYS 3	▽ STORAGES 0

Task No.	Process Symbols	Description of Task	Machine Required	Tooling Required
1	○●□D▽	MOVE TO BASE MATERIAL STORAGE	AGV-1	—
2	○⇨□D▽	LOAD BASE MATERIALS	—	—
3	○●□D▽	TRANSPORT MATERIALS TO STATION #1	AGV-1	—
4	●⇨□D▽	CUT BASE TO LENGTH		CUT OFF FIXTURE
5	○●□D▽	TRANSPORT BASE TO STATION #2	AGV-1	—
6	●⇨□D▽	HEAT BASE FOR BEND #1	STRIP HEATER	—
7	○●□D▽	TRANSPORT HEATED BASE TO STATION #3	AGV-1	—
8	●⇨□D▽	BEND BASE		BENDING FIXTURE #1
9	○⇨□D▽	DELAY UNTIL COOL		
10	○●□D▽	TRANSPORT BASE TO STATION #4	AGV-1	
11	●⇨□D▽	HEAT BASE FOR BEND #2	STRIP HEATER	
12	○●□D▽	TRANSPORT HEATED BASE TO STATION #5	AGV-1	
13	●⇨□D▽	BEND BASE		BENDING FIXTURE #2
14	○⇨□D▽	DELAY UNTIL COOL		
15	○●□D▽	RETURN TO HOME POSITION	AGV-1	

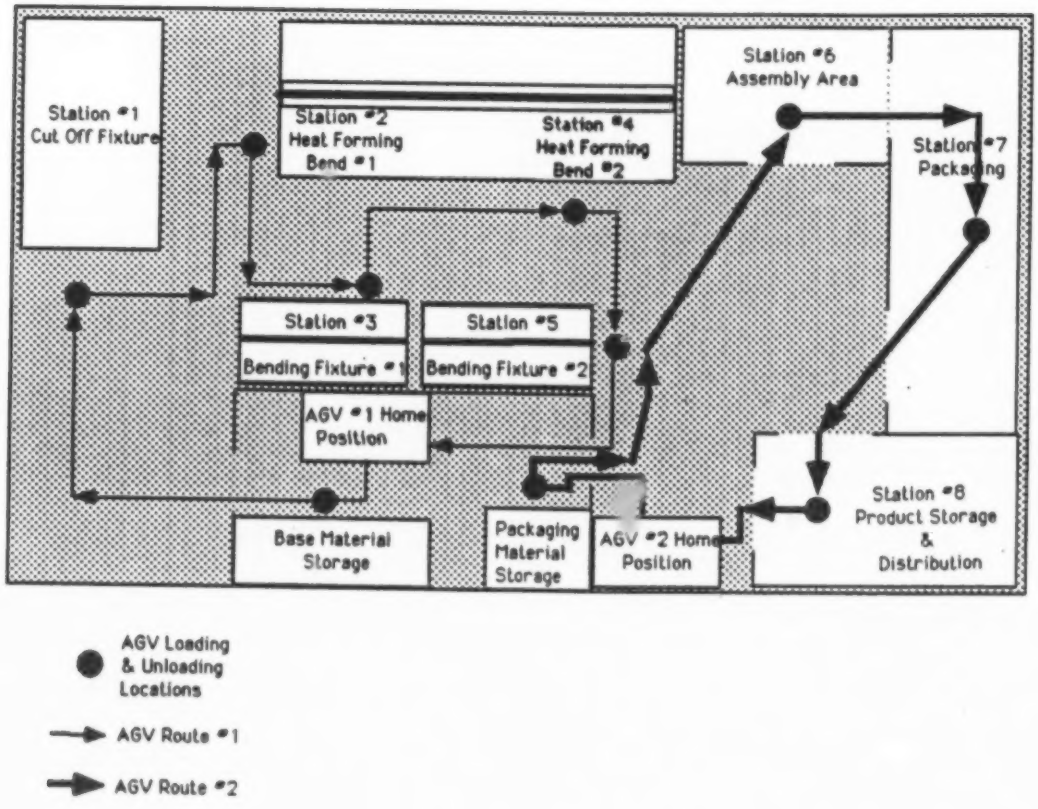
PROCESS SYMBOLS AND NO. USED	○ OPERATIONS 2 □ INSPECTIONS 2 ⇦ TRANSPORTATIONS 6 D DELAYS 2 ▽ STORAGES 1			
Task No.	Process Symbols	Description of Task	Machine Required	Tooling Required
16	○■□D▽	MOVE TO PACKAGING MATERIAL STORAGE	AGV-2	
17	○⇨□■▽	LOAD MATERIALS	—	—
18	○■□D▽	MOVE TO STATION #5 AND PICKUP BASE	AGV-2	
19	○⇨□■▽	LOAD BASE		
20	○■□D▽	MOVE TO STATION #6	AGV-2	
21	○⇨■D▽	INSPECT BASES		
22	●⇨□D▽	FASTEN PADS TO BASES	GLUE	
23	○■□D▽	MOVE TO STATION #7	AGV-2	
24	●⇨□D▽	PACKAGE THE PRODUCT	STAPLER	
25	○■□D▽	MOVE TO STATION #8	AGV-2	
26	○⇨■D▽	FINAL INSPECTION		
27	○⇨□D▼	STORE FINISHED PRODUCTS		
28	○■□D▽	MOVE TO HOME POSTION	AGV-2	
	○⇨□D▽			
	○⇨□D▽			

21-M

Sample Plant Layout



Sample AGV Routes



HUMAN PUCK

Taken from TNT (December, 1987)

Introduction

The "human puck," developed at Buffalo Grove High School, is basically an air bearing. Air bearings allow people to move heavy loads without using wheels. They reduce friction by creating a cushion of air underneath the load. With an air bearing-equipped hand truck, one person can move several tons across a flat surface almost effortlessly. Air bearings can be used to move loaded palates, heavy machinery, and/or large products in an industrial facility.

Materials and Supplies

* 1 3/4" x 4' x 4' sheet of plywood
* 1 sheet of six mil plastic, 56" wide x 56" long
* 1 plastic lid from a 3 pound can of coffee
* 1 roll of reinforced plastic packaging tape
* 1 stapler
* 1 washer and 1/2" long pan head screw
* 1 shop vacuum

Making an Air Bearing (DR #1)

1. Cut a 4' diameter disk out of the 3/4" piece of plywood.

2. Bore a hole the same size as your vacuum cleaner hose six inches from the center of the disk.

3. Stretch the six mil plastic across the bottom of the plywood disk.

4. Staple the plastic to the edges of the plywood disk, trim the excess plastic, and establish a tight seal with the packaging tape.

5. Attach the 6 mil plastic sheet to the center of the plywood disk with coffee can lid, a wood screw and a washer.

6. Using a razor knife, cut three 4" diameter holes in the plastic, one foot from the center of the disk, and 120 degrees apart.

7. Place the finished air bearing on an uncarpeted floor with the plastic side down.

8. Move the hose on the shop vacuum from the inlet to the exhaust port. Install the other end of the hose in the hole on the top of the air bearing.

9. With the vacuum on, the air bearing should inflate and move freely across the floor.

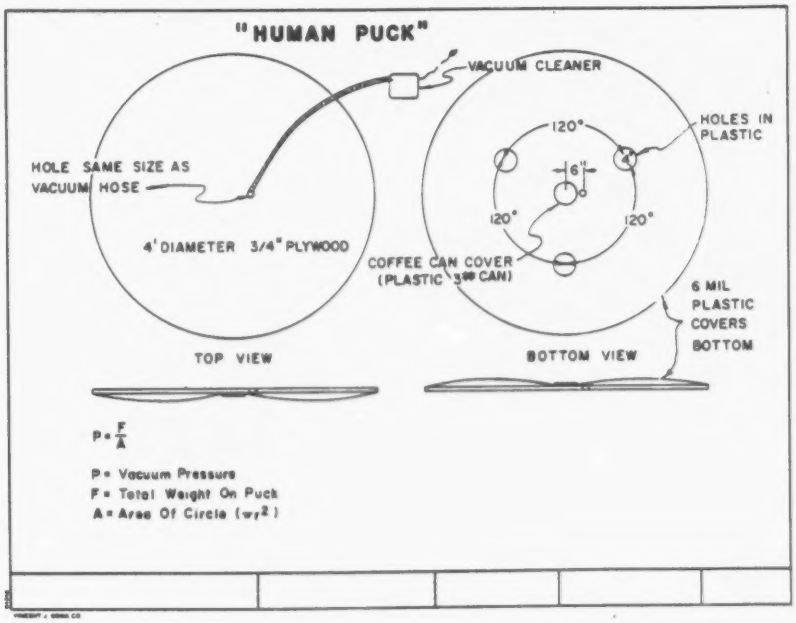
Activity Procedure

Using a bathroom scale, weigh the air bearing, one chair, and a student. Place the chair on the air bearing and have the student sit in the chair. Turn on the vacuum cleaner and try pushing the student around the room. You should be able to move the air bearing and its load across the floor with a minimum of effort. Using the formula below, deter mine the minimum amount of pressure needed to lift the load.

$$\text{Minimum Pressure} = \frac{\text{Air bearing weight, plus chair weight, plus student weight}}{\text{Area of the inflated plastic coming in contact with the floor while under load } (\pi r^2)}$$

Activity Analysis

1. Discuss the potential application of air bearing vehicles.



25-M

PIPELINE

Taken from TNT (September, 1989)

Introduction

Pipelines are a unique form of transportation technology because the cargo is mobile while the vehicle is stationary. They are typically very reliable, inexpensive to operate, easy to maintain, and they are usually concealed underground. However, they require a high initial investment and have a fixed cargo capacity and route. Most pipeline systems have a network of gathering, transmission, and distribution pipelines. In addition, they have pumping stations to apply pressure to the cargo, control stations to monitor and adjust the flow of cargo, measuring stations to monitor the amount of cargo flowing, and exchange stations to move cargo from one pipeline to another. The two most common materials transported by pipeline are crude oil and natural gas.

Materials and Equipment:

* 3 large graduated containers
* 1 generic automotive windshield washer pump
* 4 pieces of wood 3/4" x 4" x 6"
* 1 brass aquarium gang valve
* 1 3 foot length of 1/8" hose
* 12 volt power supply or 2 6 volt dry cells and an on/off switch
* A variety of screws and washers
* Water

Problem Statement

ACME Petroleum has just opened a new oil well five miles away from two refineries, Petro Products and Refined Fuels, Incorporated. Unfortunately, neither refinery has the capacity to process all the crude oil because of commitments with other petroleum companies. Petro Products estimates it can handle 66 per cent of the crude from the well and Refined Fuels can process the balance. They might be able to handle more crude oil when their contracts with other petroleum companies expire. ACME Petroleum is currently pumping the crude oil into storage tanks and shipping it to the refineries by truck at great expense. Being a transportation consultant, you feel a pipeline is the most cost effective way to get the crude oil to the refineries. Build and present a working model that will help the president of ACME Petroleum understand how a pipeline can solve his/her company's transportation problems.

Activity Procedure

1. Assemble the wood bases for the windshield washer pump and aquarium gang valve. Mount the windshield washer pump to one base and the aquarium gang valve to the other.
2. Using the illustration as a guide, position the graduated containers, windshield washer pump, and gang valve. Cut and install the hose between the various components.
3. Fill container closest to the pump with water. Connect the positive and negative leads from the windshield washer pump to the power supply. Position the power supply away from the water.

4. Open both valves so water can flow freely. Turn on the power supply and water should begin to flow from the water supply to the two graduated containers. Slowly close the valves to adjust the water flow. DO NOT close the valves completely. Closing both valves can damage the pump or cause hoses to burst off of their fittings.

Activity Analysis

1. Identify the roles being played by the graduated containers ACME Petroleum, Petro Products, and Refined Fuels), windshield washer pump (pumping station), aquarium valve (control and exchange station), and hoses.

_____

_____

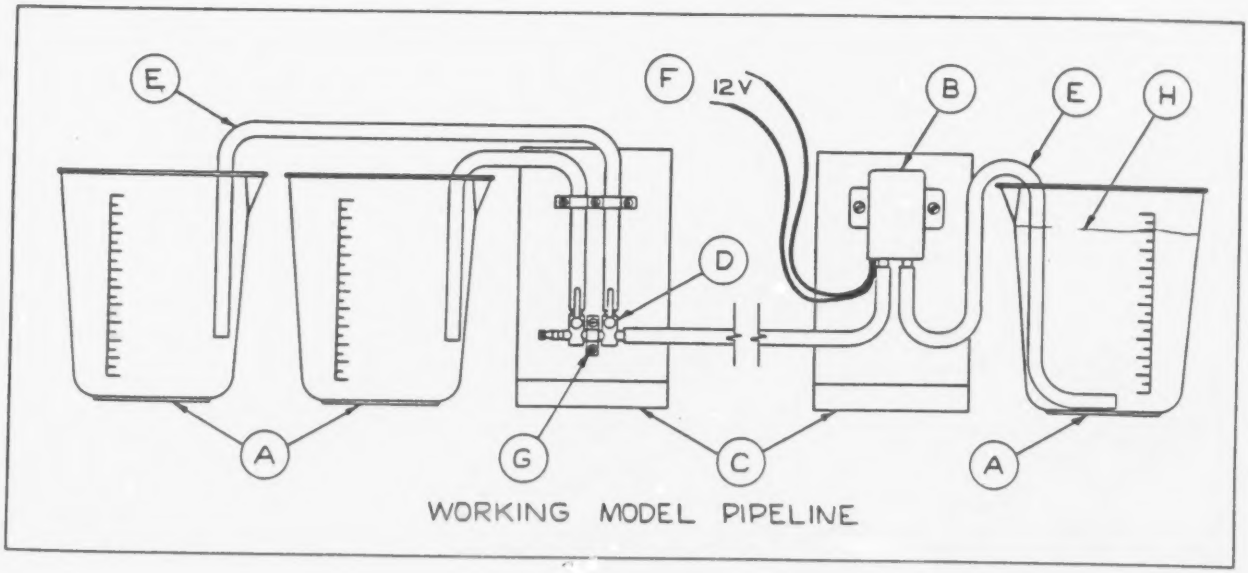
_____

2. Determine how many barrels (42 gallons or 158.4 liters) of crude oil per minute could be transported if the proposed pipeline can pump 1,000 times more than your model pipeline.

_____

_____

_____



WORKING MODEL PIPELINE

27-M

WATER TRANSPORTATION TECHNOLOGY

WATER TRANSPORTATION SYSTEMS

Suggested Learning Objectives

Upon completion of the water transportation technology unit, students will be able to:

A. Define and properly use common manufacturing **terminology** like berth, rigging, nautical mile, buoyancy, intracoastal, tonnage, waterway, bow, stern, port, dead reckoning, mariner's chart, and bearing.

B. Identify basic **applications** for water transportation technology like transporting people, providing recreation, and moving energy resources, raw materials, grain and products.

C. Identify basic natural, human, material, financial, technological, and informational **resources** used in water transportation processes, and enterprises.

D. Describe the social and environmental **impacts** associated with water transportation activities including water pollution, oil spills, and efficient transportation of bulk cargo. SC2

E. Describe the major milestones in the **history** and evolution of water transportation including the triumphs of the Spanish Armada, accomplishments of explorers like Columbus and La Salle, the Titanic disaster, construction of the Panama Canal, and the development of Japanese Shin Aitoku Mara. SS2

F. Identify, describe, and evaluate **career** opportunities related to water transportation technology (e.g., navigator, dock worker, merchant marine) based on their interests, talents, and career expectations.

G. Identify potential **safety** hazards, establish guidelines for safe behavior and adhere to common safety practices when around or participating in water transportation activities. PH3

H. Describe the major processes used in water transportation including shipping, exporting, importing, routing, docking, navigating, loading, unloading, towing, and trimming.

I. Describe and forecast the implications of innovative water transportation technologies like nuclear super tankers, air cushion crafts, hydrofoils, containerization, and LASH/Seabee vessels. SC2

J. Discriminate between boats and ships.

K. Describe the advantages, disadvantages, and potential applications for various water transportation systems like hydrofoils, barges, super tankers, and hovercraft. SC2

L. Evaluate water transportation systems like barges, tankers, jetfoil, and air cushion based on equipment, human resources, materials, cost, quantity, and time considerations.

M. Forecast the potential effects of innovative water transportation technologies on recreation, commuter transportation, water pollution, and international trade. SC2

N. Describe the basic payload, guidance, propulsion, control, and support systems for a given mode of water transportation.

O. Determine the optimum means of transporting a given payload based on departure, destination, cost, time, energy, safety, and environmental considerations.

Suggested Learning Experiences

1. Discuss the role of locks and dams on various waterways. explain how they use technology to adjust for changing elevations on waterways. Using materials like plexiglas, plastic hose, windshield washer pumps, and various fittings, have students in small groups design, build, test, and demonstrate a model lock and dam system that will transport a vessel from one elevation to another. Ask students to identify and evaluate the potential economic benefits and environmental impacts associated with building a lock and dam on a river.

2. Introduce students to the concept of buoyancy and how it applies to hull design and transporting a payload over water. Using tools and materials like polystyrene sheets, wooden molds, and a vacuum former, have students design, build and test a model barge that will transport a given cargo. Possible design considerations could include things like the depth of the waterway, the weight of the cargo, the cargo's volume, and the amount of material that can be used to make the barge. When students have finished testing and evaluating their model barges, have them describe the relationship between hull area, payload weight, and buoyancy. Discuss the advantages, disadvantages, and applications of barge technology as means of transporting cargo.

3. Discuss the various propulsion systems used to power small boats and large ships. Include wind, diesel, steam turbine, diesel/electric, turbine/electric, and nuclear propulsion systems in the discussion. Using materials like hobby motors, batteries, steel rods, and sheet metal, have students design, install, and test a propulsion system for the hulls developed during the activity above. Have students compare and contrast the types of propulsion systems used for recreational and commercial vessels. Discuss how energy, cargo, waterway, and hull considerations influence the type and size of the propulsion system.

4. Discuss the technologies used to control the velocity and direction of small boats and large ships. Using switches, variable resistors, and pieces of polystyrene plastic, have students design, install, and test control systems that enable their vessels to slow down, speed up and turn left or right. Have students identify the limitations of the control systems on large vehicles.

5. Discuss the role of wind energy in propelling recreational boats and commercial ships. Explain how various sail configurations harness the wind and propel boats and ships. Using tools and materials like polystyrene sheets, wooden molds, dowel rods, cloth, and vacuum formers, have students design and build model sailing vessels based on past, present, and/or future ship designs. Use portable fans and a large water container to test each design. Have students identify and describe the energy conservation and environment advantages of using wind energy to propel boats and ships.

6. Explain how submarines and submersibles use air and water to submerge or surface. Have students connect a balloon to one end of a plastic hose and a squeeze bottle to to the other end. Insert the balloon into a second plastic bottle and place in a tank of water. Allow the bottle to fill with water and sink to the bottom of the tank. Compress the squeeze bottle to inflate the balloon and cause the model to surface. Discuss how submersibles are used to conduct research and salvage work under water.

7. Discuss how hovercrafts are being used to transport people and goods across bodies of water. Explain how they travel over land and water on a cushion of air. Using materials like hobby motors, model airplane propellers, styrofoam, and plastic bags, have teams of students design, build, and test model hovercrafts. Ask each team to demonstrate and present their hovercraft to the rest of the class. Require presenters to identify and describe their hovercraft's propulsion, guidance, control, and payload systems.

8. Introduce students to the concept of a hydrofoil and how hydrofoil technology is being used to make ferry transportation faster and more comfortable. Using materials like Fiberglas, polyester resin, wood molds, and model rocket engines or two cycle hobby engines, have small groups of students design, build and test model hydrofoils that can travel across a body of water. Ask students to explain how hydrofoils reach high speeds by reducing drag.

9. Discuss the milestones in the history of water transportation technology. Assign each student a historical event. Using library resources, have students gather information and develop an abstract describing the people, dates, places, and impacts associated with their assigned event. Encourage students to illustrate their abstracts. Post each abstract on a large timeline. Ask students to describe how given events influenced our culture and subsequent technological developments.

10. Discuss the career opportunities in water transportation technology. Include occupations at the non-skilled, semi- skilled, skilled, technician, and professional levels in the discussion. Using library and guidance resources, have students gather information and present a short written or verbal report about an occupation related to water transportation technology. Each report should include information about the educational requirements, working conditions, benefits, salary, and advancement potential related to the occupation. Ask students to evaluate the career based on their interests, talents, and career expectations.

HULL DESIGN AND BUOYANCY

Introduction

Why do large steel ships float? In order to understand why, you first need to know something about bouyancy. Buoyancy is the upward force on an object in a liquid. Buoyancy is effected by an object's weight or density and volume. Weight is the downward force or gravity pushing against the object. Volume indicates how much fluid the object displaces. If the object is more dense or weighs more than the fluid it displaces, the object will sink. If the object is less dense or weighs less than the fluid displaced, the object will float.

This Techonology Education Activity will allow students the opportunity to see how a ships hull design is effected by buoyancy and payload capacity.

Materials and Supplies

Provide each group of two students the following materials:

* 3"x3"x3" cube of modeling clay
* Weights (e.g.,1/2" Hex nuts, marbles, 1/2" washers)
* a container approximately 4" deep, 12" wide and 15" long to hold water (e.g., a sink, small fish tank, plastic food storage container)
  Note: The container can be shared by more than one group.

Optional:

* A scale (sensitive enough to measure small amounts of weight)
  Note: The maximum payload capacity can be determined by counting item (e.g., 1/2" hex nuts) added to the design.

Problem Statement

You are part of a design team for a ship manufacture. Your team has been ask to create a new hull design for a barge. The new design should be capable of holding large payloads. Since your company is in competition with several other ship manufactures, it is up to your team to design a hull that will hold the most weight without sinking.

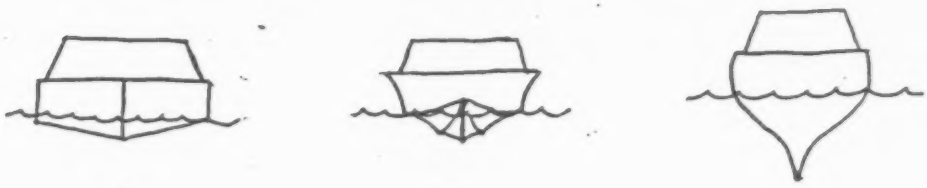
Activity Procedure

1. Each groups of two should have some clay and access to a test tank.
2. Using the clay, shape a hull design. Remember your team is in competion with other companies, so keep your designs confidential.
3. Using the test tank, carefully place the clay model into the tank of water. If the design does not float, either make modifications or develop a new design. If the design floats, test it for payload capacity by adding small amounts of weight until the hull sinks.
4. Keep modifying the design until your team is satisfied that they have the best design.
5. Once all groups have completed their designs, have each team compare and test their designs.

Activity Analysis

Based on the experience gained by conducting this activity.

1. Which hull design shown below would be best suited for an oil tanker? Please circle one.



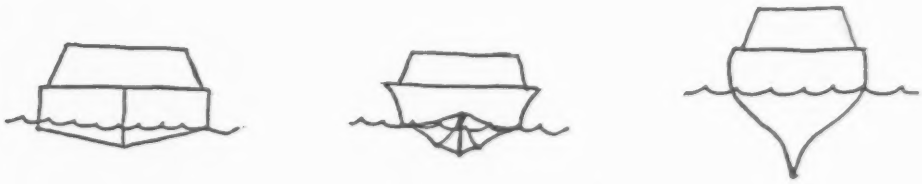
A B C

Explain why?_____

_____

_____

2. Which hull design shown below would be best suited for a speed boat? Please circle one.



A B C

Explain Why?_____

_____

_____

3. In order to make fifty pounds of lead float, you would have to:

a. increase the weight of the cube.
b. decrease the volume of the cube.
c. increase the density of the cube.
d. increase the volume of the cube.

AIR-CUSHION VEHICLES

Introduction

Air-cushion vehicles, more commonly referred to as hovercrafts, travel on a cushion of compressed air. Large fans are used to blow air under the vehicle and create enough pressure to lift the vehicle above the surface. One or more large aircraft propellers pointing to the rear of the vehicle are used to create the thrust that moves the vehicle forward.

To control the amount of air escaping under the vehicle, a large skirt is fitted around the base of the vehicle. The skirt is typically made out of a rubberized fabric and it inflates like a large inner tube when the fans are engaged. The flexibility of the skirt allows the ACV to maintain its cushion when traveling over small obstacles and waves.

Since ACV's travel on a cushion of air, there is very little friction between the vehicle and the surface it is traveling on. Because of this lack of friction, an ACV can travel very fast while using a lot less energy than conventional vehicles. However, this lack of friction makes steering an ACV very difficult. Large ACV's use a combination of aircraft-type rudders, swiveling propellers, and/or increasing the amount of thrust on one side of the vehicle or the other to steer the vehicle.

Air-cushion vehicles are amphibious -- they can travel on either land or water. ACV's are especially useful for traveling over swamps. They have been used for scientific expeditions in South America and military operations in South Vietnam. ACV's are being commercially used to ferry passengers and automobiles from Dover, England and Boulogne, France.

ACV's have significant limitations. They cannot travel on rough seas, cross rocky ground or wide ditches, or climb sloping ground. The aircraft-like engines used on ACV's are very noisy. Lastly, because ACV technology is still new, they are very expensive to build and operate. Even with these problems, with additional research and development, ACV's could someday replace conventional displacement ships for many transportation applications.

This Technology Education Activity will provide students with an opportunity to make and test a simple air-cushion vehicle.

Materials and Supplies

Each design team needs access to scrap:

* styrofoam insulation about 1" thick
* poster board
* sheets of plastic about 1 mill thick (the kind used for garbage bags)
* sheet metal strips about 1 inch wide

Each design team will need at least:

* 2 hobby motors
* 1 roll of masking tape
* 2 SPST toggle switches
* 1 6-volt battery
* 2 model air plane propellers about 4" long
* 2 x-acto knives

Problem Statement

You are a designer at Water Modes, Incorporated. Marshland Recreations has hired your firm to design and build a unique water vessel. Marshland Recreations has developed a 500 acre island into a hunting and fishing resort. Unfortunately, the island resort is surrounded by marshes and swamps. Because the surrounding water is very shallow and full of vegetation, ferrying people to and from the island resort with a conventional boat has proven to be unreliable. Clearing the vegetation and dredging the swamp would endanger the fish and wildlife. The owners hope Water Modes, Incorporated can solve their transportation problem.

After visiting the resort, the engineering department feels the only solution to the problem is an ACV. In order for the sales department to convince Marshland Recreations, they want to demonstrate how an ACV works. Therefore, your job is to develop a model ACV that can travel across the floor on a cushion of air. Except for a battery and an on/off switch, the vehicle must be able to carry its own weight.

Activity Procedure

1. Discuss with your team members various ways you could make a model ACV. Consider using a variety of materials. Try not to evaluate each idea right away. The most impor tant thing is to develop as many ideas as possible and to record each idea in the form of a sketch (SH #1).

2. After you have developed several designs, evaluate each design carefully, select the best design, and/or combine several good ideas into one final design (SH #1).

3. Using available materials, build a working model of an ACV that includes a lift and propulsion system.

4. When you have finished making your model, hook up the battery, try it out on a clean flat surface, identify problems, and make needed modifications and refinements.

5. Prepare a demonstration for your ACV. Your demonstration should include:

   A. a statement of the problem.
   B. a brief description of how your model ACV establishes lift and how it is propelled forward.
   C. a demonstration of how your ACV works.

6. When your teacher tells you it is your turn, present your ACV demonstration.

PRELIMINARY IDEAS FOR MARSHLAND REC.
WATER MODES, INC.

FINAL ACV DESIGN FOR MARSHLAND REC.
WATER MODES, INC.

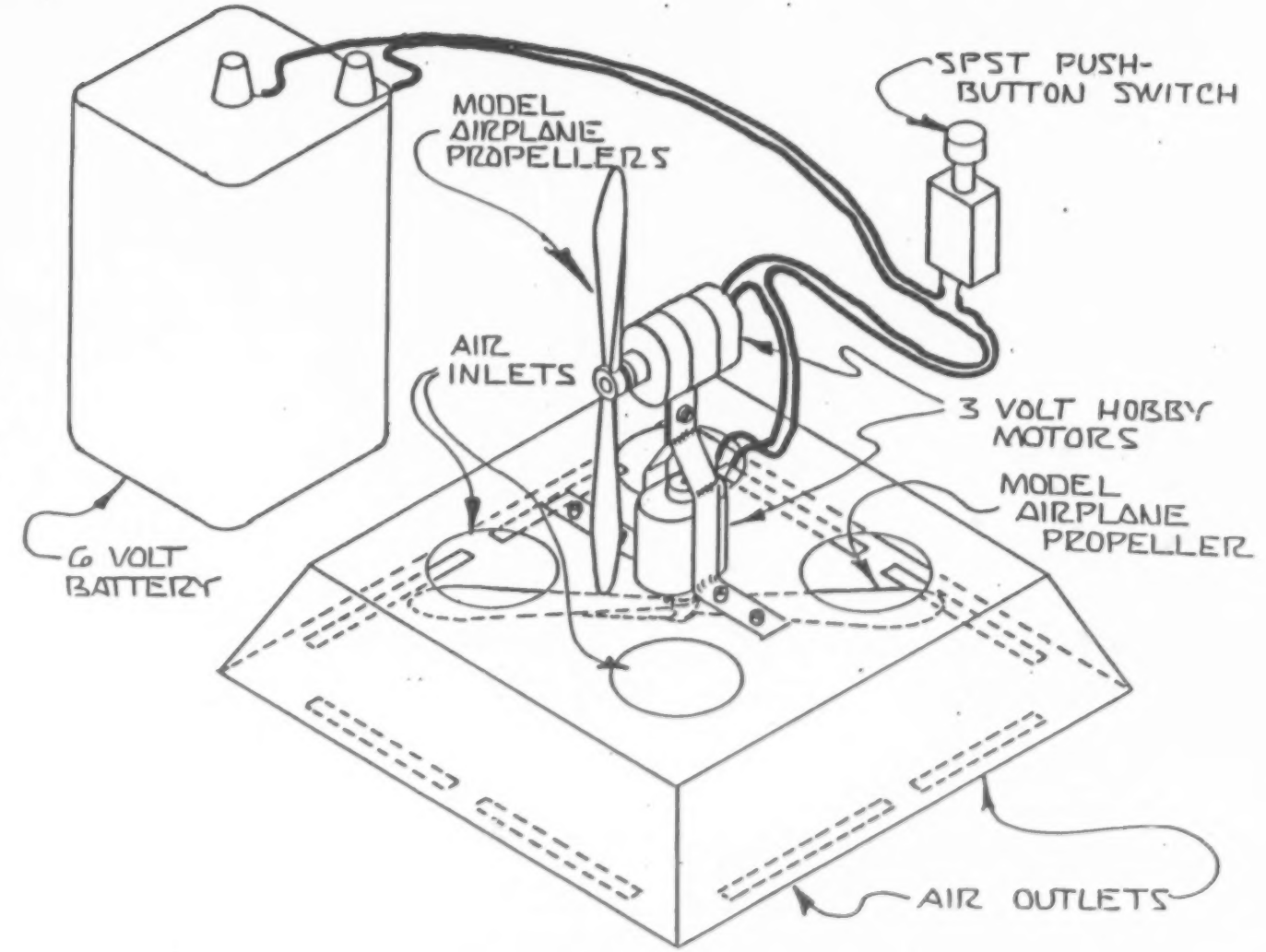


FIGURE 1
EXAMPLE MODEL ACV

SUBMARINES AND SUBMERSIBLES

Introduction

A ship that operates under the surface of the water is referred to as a submarine. The first demonstration of such a submarine was the covering of a wooden rowboat covered with waterproof hides in 1620. Little was done with the development of such an under water vehicle because of the slow development in technology until the Revolutionary War (1775-1783). The first one-man submarine was powered by a hand cranked propeller. The idea of traveling below the surface of the water succeeded but it failed in an attempt to sink a British war ship. Several improvements were made to the underwater vehicle and in 1900, the Navy bought its first submarine. It could sink, surface, move forward with the use of a gasoline engine and electric batteries, and also had lateral movement. The modern submarine is nuclear powered and virtually has unlimited range. They are capable of operating well below 400 feet (120 meters) and reach speeds of 30 knots. Only special designed research submarines called submersibles can dive deeper than 5,000 feet (1,524 meters). Their hulls are designed to resist the intense pressure that would crush an ordinary submarine in seconds.

A submarine travels under water similar to an airplane moving through air. Rudders are used to raise or lower the vehicle or to move the underwater vehicle left or right. A submarine dives by flooding its ballast tanks with water (SH #1). The added weight causes the ship to lose its positive buoyancy. Positive buoyancy is the ability of any ship to stay on the water's surface. The ballast tanks are filled until neutral buoyancy is obtained. This is when the ship floats under the surface of the water. By doing floating under the surface the vehicle can be guided up or down with the rudders. To resurface the submarine, water is blown out of the ballast tanks by compressed air. This causes the submarine to become positive buoyancy again and move toward the surface of the water.

Nuclear submarines produce their own air and drinking water by a process called electrolysis. This process extracts oxygen from sea water and uses the oxygen for the crew and for compressed air for the crew. To determine a submarine's location, an inertial navigation system is used. It consists of an accurate measuring device that is linked to a modern computer.

In this activity, you will develop a submersible vehicle that will demonstrate positive buoyancy, neutral buoyancy, and negative buoyancy using the materials provided by your instructor.

Materials and Supplies

* Overhead projector
* Plastic hose (3')
* Plastic squeeze bottle
* Plastic bottle
* Electric drill
* 1/4" twist drill
* Balloons (shape of plastic bottle)
* Large container for water
* Hot-glue gun
* Utility knife

Activity Procedure

1. Watch the demonstration that your instructor gives to the class.
2. Listen to the presentation that your instructor gives to the class on the topic of submarines or submersibles.
3. Pick up the materials that your instructor has laid out for each group.
4. Read through the following problem. Construct a vehicle that demonstrates positive buoyancy, neutral buoyancy, and negative buoyancy using only the materials given to your group.
5. Before you start cutting or gluing any material, use a piece of paper to make some preliminary sketches of ideas on how to solve the problem.
6. Have the group decide on one idea and then start building the submersible using only the materials provided.
7. After assembling the submersible, your group should experiment with it in the water tank to see if it will work.
8. Any changes can be made at this time back at the work station.
9. Your instructor will have each group demonstrate how your solution to the problem works. Make sure you explain the positive, neutral, and negative buoyancy concepts as you demonstrate your underwater vehicle.
10. Clean up all materials and tools in the laboratory and return to your station.

Activity Analysis

1. Explain how submarines use air, weight and water to surface and dive.

_____

_____

_____

2. What is

   a. positive buoyancy

_____

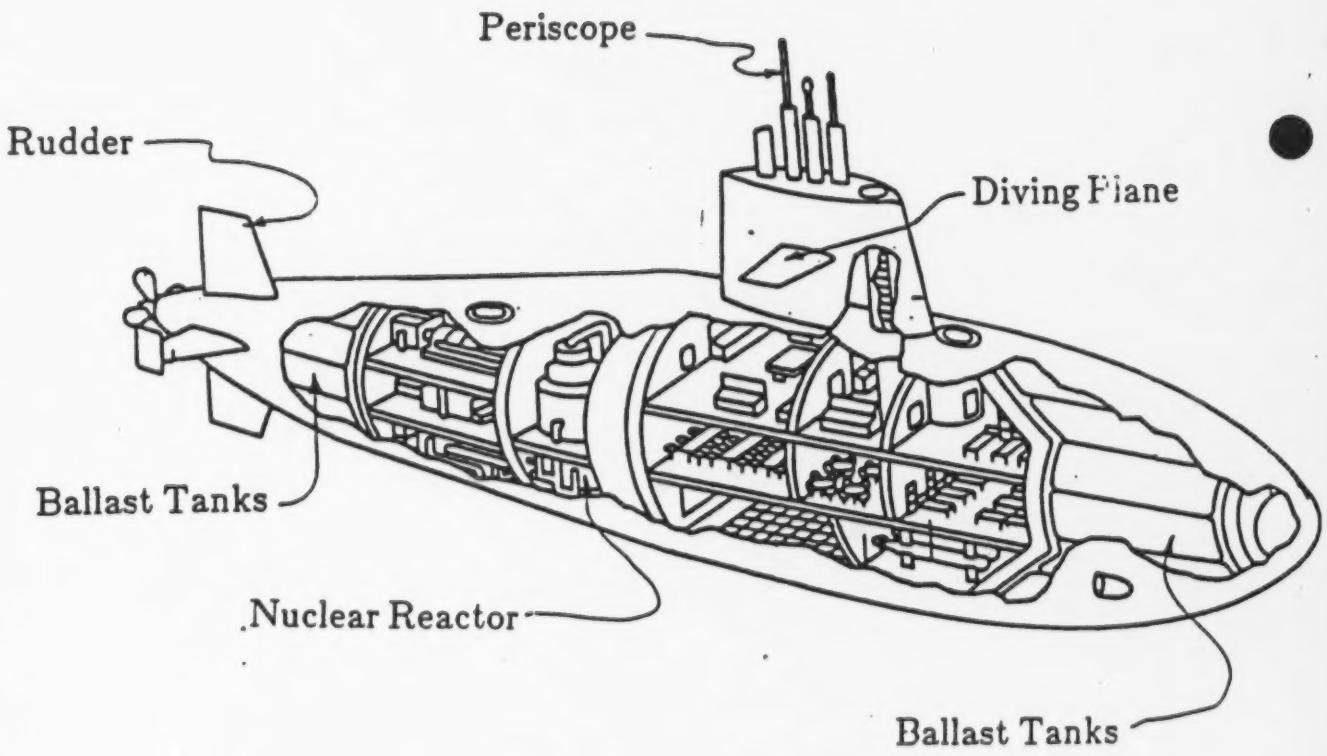
_____

   b. negative buoyancy

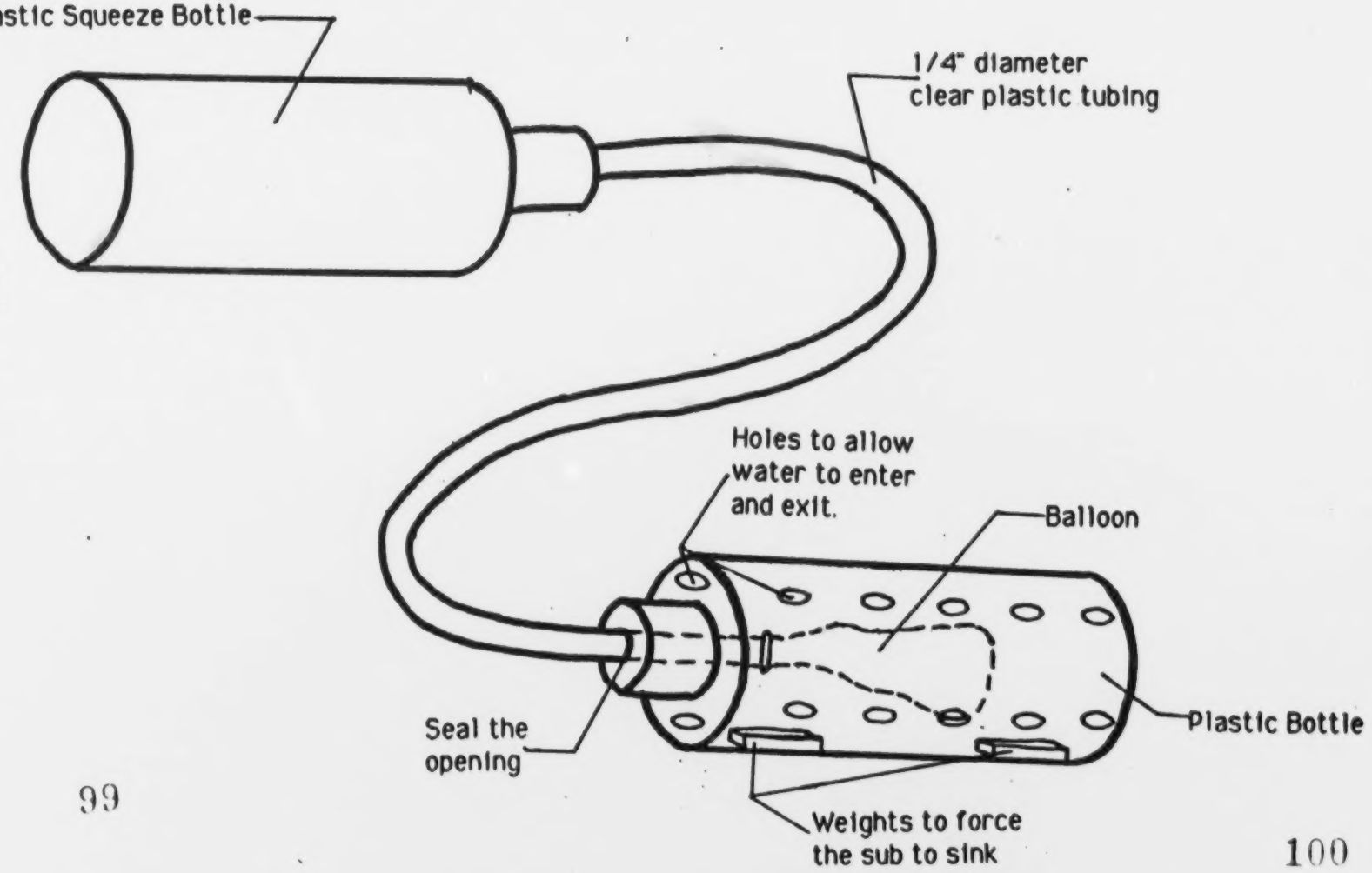
_____

_____

SUBMARINE DETAIL



Sample Model Submarine



AIR TRANSPORTATION TECHNOLOGY

AIR TRANSPORTATION SYSTEMS

Suggested Learning Objectives

Upon completion of the air transportation systems unit, students will be able to:

A. Define and properly use common air transportation **terminology** like radar, air traffic control, eddy current, fuselage, angle of attack, FAA, gates, airways, and instrument flight rules (IFR).

B. Identify basic **applications** for air transportation technology including carrying mail, shipping goods, providing recreation, and transporting people.

C. Identify basic natural, human, material, financial, technological, and informational **resources** used in air transportation processes and enterprises.

D. Describe the major **processes** used in transporting people and goods by means of air transportation including scheduling, planning, dispatching, navigating, controlling, landing, guiding, propelling, lifting, and thrusting.

E. Describe the social and environmental **impacts** associated with air transportation activities including air and sound pollution, land utilization, airport and air traffic congestion, rapid transportation, accidents. SC2

F. Describe the major milestones in the **history** and evolution of air transportation including the development of hot air balloons, Hindenberg disaster, first flight by the Wright brothers at Kitty Hawk, the introduction of the jet engine, and the use of composite materials. SS2

G. Identify and evaluate **career** opportunities in air transportation (e.g., air traffic controller, commercial pilot, flight attendant) based on interests, talents, and career expectations.

H. Identify potential **safety** hazards, establish guidelines for safe behavior, and adhere to common safety practices when around or participating in air transportation activities. PH3

I. Design, build, and test model aircraft that addresses design considerations like aerodynamics, stability, control, and guidance.

J. Use common tools, materials, and processes to design, build, test, and modify model aircrafts and to simulate an airplane flight.

K. Describe the advantages, disadvantages, and potential applications of various air transportation systems like airships, gliders, prop planes, jet planes, and helicopters. SC2

L. Describe and forecast the implications of innovative air transportation technologies like STOL, VTOL, SST, and telemetry on competitiveness, air safety, and efficiency. SC2

M. Discriminate between lighter-than-air, prop, jet, and rotary-wing aircrafts.

N. Describe the basic payload, guidance, propulsion, control, and support systems for a given mode of air transportation.

O. Determine the optimum means of transporting a given payload based on departure, destination, cost, time, energy, safety, and environmental considerations.

Suggested Learning Experiences

1. Demonstrate how an airplane wing produces the lift needed to fly. Test a cross section (air foil) of an aircraft wing suspended in a commercial or constructed wind tunnel. Explain how Bernoulli's theories and Newton's third law of motion (every action has an equal and opposite reaction) produces lift. Manipulate the air foil angle of attack and determine the stall angle. Discuss the relationship between angle of attack and lift.

2. Introduce students to the concept of aeronautics. Identify the basic component of an airplane and discuss how each plays a part in flight. Using balsa, foamcore, styrofoam, cardboard, and/or paper, have students make model airplanes. Design considerations should include things like size, weight, wing shape, propulsion system, and control devices. Ask students to explain how application (e.g., military, commercial, private) can effect the design of the aircraft.

3. Discuss how wind tunnels are used to test the laws of aerodynamic and engineering principles. Using a commercial or constructed wind tunnel, have groups of students evaluate and modify the airplane produced during the activity above. Have each group evaluate and inspect their aircraft for structural defects, points of instability, and flaws in aerodynamic design. Have students discuss how wind tunnels can be used to improve things like fuel efficiency, safety, and aerodynamics.

4. Introduce students to the concept of thrust. Using things like a plastic propeller and rubber band, CO_2 cartridge, or solid rocket engine, have students develop a propulsion system for their model airplane. Discuss the consequences of propulsion system failure on various types of aircraft. Have students evaluate efforts to make air transportation even faster than it is today.

5. Discuss how ailerons, elevators, and rudders are used to control an aircraft in flight. Have each student install and/or manipulate control devices that will enable their model plane to fly straight, bank right or left, and increase or decrease altitude. Conduct a competition modeled after the International Paper Airplane Contest to determine whose airplane flies the furthest. Have students explain how weight, thrust, flight path, wing span, and control systems effect the distance traveled.

6. Introduce students to the concept of computer flight simulation. Using a computer and one of the popular flight simulation programs, have each student perform common flight maneuvers (e.g., take-off, bank, land) for an assigned flight plan. Possible flight plans could include things like using a specific type of aircraft, flying at night, landing at various airports, or maneuvering around obstacles, or flying over various types of terrain. Have students discuss the role of flight simulators in training and updating pilots.

AIRFOIL DESIGN

Introduction

As an airplane flies through the air, four forces are acting on it. These forces are lift, drag, gravity, and thrust (see Figure 1). Lift is the upward force that causes the plane to rise. Gravity is the downward force pulling the plane toward earth. Drag is the backward force caused by wind. Thrust is the force which causes the plane to move forward.

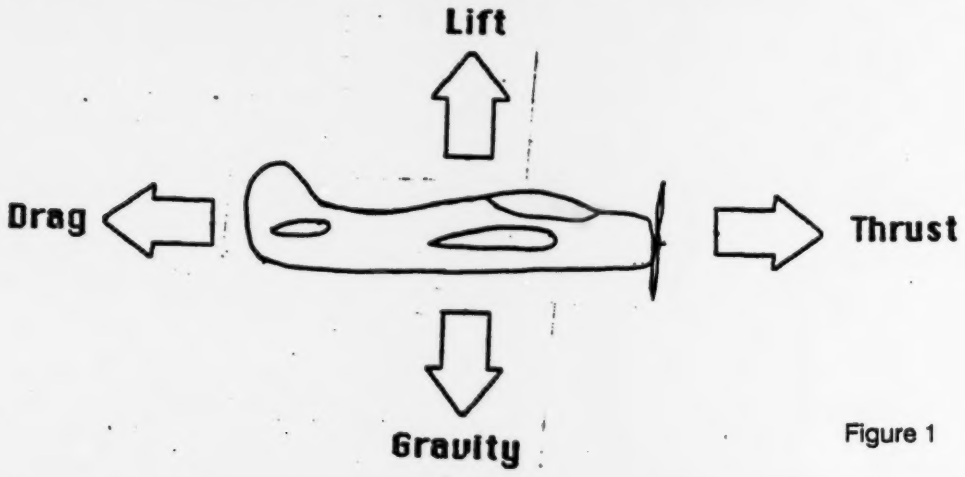


Figure 1

On an aircraft, lift is produced by airfoils or wings. To understand how the airfoil produces lift, you must understand Bernoulli's Principle. Bernoulli's principle states when air flows over a surface, its pressure decreases as the speed of the air increases. Because of the shape of an airplane's wing, the air moves faster over the top (see Figure 2). This causes a pressure difference, low pressure above the wing, and high pressure underneath the wing. This pressure difference results in the wing lifting. If the air moving over the wing is not fast enough, the plane will stall.

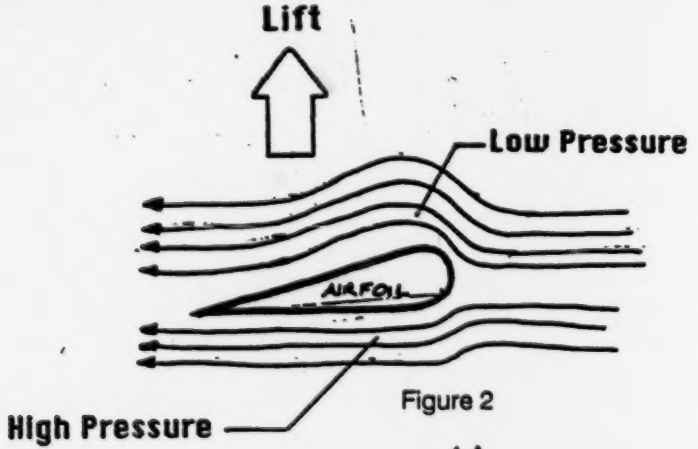


Figure 2

4-A

7. Discuss how airplanes use lift and drag to maintain altitude and carry a payload. Using materials like balsa, plastic, string, and paper, have small groups of students design, build, and test model gliders that will carry an assigned payload from a given elevation to a specific target on the ground. On a windy day, have students launch their model aircrafts from an upper story window or the top of the football bleachers to a large target several yards below. Award points based on how close they can get their airplane to the center of the target. Have students identify and describe the relationship between things like flight duration, wing span, payload weight, and wing shape.

8. Introduce students to the concept of lighter-than-air vehicles. Using materials like glue, black garbage bags, clear plastic, and kite string, have small groups of students design, build, and test a hot air balloon that uses solar energy and/or a hair dryer to create lift. Ask students to explain why lighter-than-air vehicles are not widely used. Have students forecast how lighter-than-air vehicles might be used in the future.

9. Introduce students to the concept of rotary-wing aircraft. Using things like a rubber band for a power source, a piece of cardboard for a stabilizer, balsa wood for a fuselage, and a propeller to provide lift, have a group of students design, build, and test a model helicopter. Ask students to compare applications for helicopters and airplanes. Have students discuss how experimental aircrafts using short takeoff and landing (STOL) and vertical takeoff and landing (VTOL) technologies could change air transportation systems in the future.

10. Introduce students to the concept of airport design. Using materials like construction paper, cardboard, foamcore, plastic cups, straws, and glue, have a small group of students design, build, and present an architectural model for a rural, metropolitan, commercial, and/or private airport. Each model should include features like a passenger terminal, runways, taxiways, air traffic control, people moving systems, parking, and hangers. Have each group present how their airport design addresses important considerations like land utilization, noise pollution, safety, expansion, and traffic. Ask students to discuss the importance of long term planning when designing air transportation facilities.

11. Discuss the milestones in the history and evolution of air transportation technology. Assign each student a historical event. Using library resources, have students gather information and develop an abstract describing the people, dates, places, and impacts associated with their assigned event. Encourage students to illustrate their abstracts. Post each abstract on a large timeline. Ask students to describe how given events influenced our culture and subsequent technological developments.

12. Discuss the career opportunities in air transportation technology. Include occupations at the non-skilled, semi-skilled, skilled, technician, and professional levels in the discussion. Using library and guidance resources, have students gather information and present a short written or verbal report about an occupation related to air transportation technology. Each report should include information about the educational requirements, working conditions, benefits, salary, and advancement potential related to the occupation. Ask students to evaluate the career based on their interests, talents, and career expectations.

This Technology Education Activity will allow students the opportunity to experience Bernoulli's Principle by designing and testing an airfoil.

Materials and Supplies

* Access to a wind tunnel (DR #1) (SH #1)
* Test stand (DR #1)
* 1 balance scale
* 2 pieces of easy-to-form material approximately 1/2" thick x 2 1/2" wide x 4" long (e.g., styrofoam, pine, balsa wood).
  NOTE: For this activity, balsa wood will be used.
* Shaping materials (e.g., wood rasp, sand paper, stationary belt sander)
* Several sheets of 1/8" grid paper
* Pencil
* French curve
* Scissors
* Tape

OPTIONAL: The design portion of this activity can be enhanced by using a computer and a simple CAD program.

Problem Statement

You are a member of a research and development department of a major aircraft manufacturing company. The head of the research and development department has assigned your division the task of designing and testing a new wing design.

Activity Procedures

1. Each group of two or three should obtain the materials needed to complete the activity.
2. Using either traditional or computer-aided drafting techniques, draw three possible airfoil designs.
3. After your group has completed the three designs, select the best two designs. Be sure to select the designs you feel will produce the most lift.
4. Using scissors, cut out the shape of the airfoils
5. Carefully trace the shape of the airfoil onto the end of the piece of balsa wood.
6. Use the sand paper and carefully shape the balsa wood to match the design.
7. Once you have finished the two designs, the next step is to test them for lift in the wind tunnel.
8. Set up the balance scale as shown in DR #1.
9. Next, fasten the airfoil to the test stand.
10. Using the tape, attach the test stand to the balance scale. Set the scale to zero.
11. Turn on the blower. How much lift did the airfoil produce? _____
12. Turn the blower off and repeat steps 8-10 for the second design.
13. Turn on the blower. How much lift did the airfoil produce? _____

Activity Analysis

1. Did your airfoil produce lift? _____ If yes, explain why the airfoil lifted when the air passed over it. If no, explain why the airfoil did not lift as the air passed over it.

_____

_____

_____

2. If the air passing over the wing of an airplane is too slow, the plane will _____

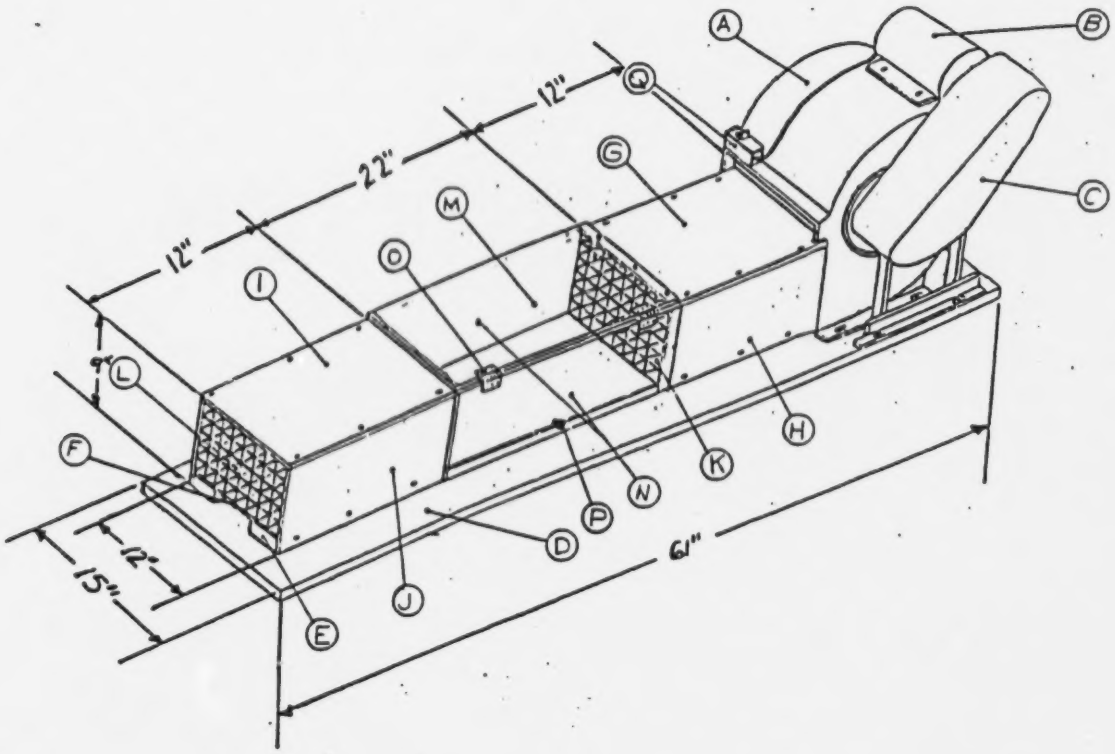
   a. lift
   b. stall
   c. land
   d. level off

3. Of the four forces which act on an airplane, which one is directly affected by the airfoils?

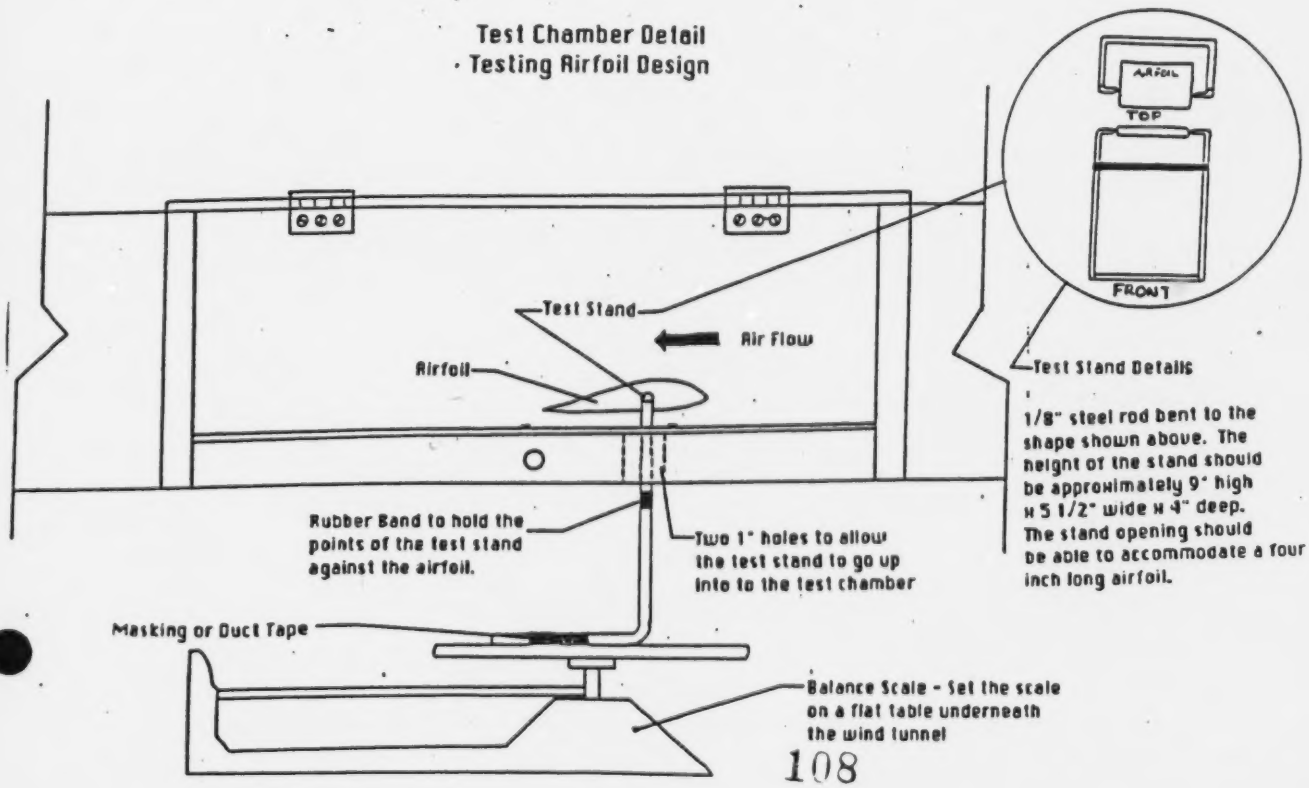
   a. gravity
   b. thrust
   c. lift
   d. drag

Wind Tunnel

DR #1



Test Chamber Detail
· Testing Airfoil Design


AIRFOIL
TOP
FRONT
Test Stand
Air Flow
Airfoil
Test Stand Details
1/8" steel rod bent to the shape shown above. The height of the stand should be approximately 9" high x 5 1/2" wide x 4" deep. The stand opening should be able to accommodate a four inch long airfoil.
Rubber Band to hold the points of the test stand against the airfoil.
Two 1" holes to allow the test stand to go up into to the test chamber
Masking or Duct Tape
Balance Scale - Set the scale on a flat table underneath the wind tunnel

BILL OF MATERIALS FOR A FURNACE BLOWER WIND TUNNEL

PART		DESCRIPTION & PROCEDURES
A	*	Furnace blower - NOTE: **The actual construction of your wind tunnel may vary from the process described below due to the various styles of furnace blowers available.**
B	*	Furnace blower motor
C	*	Sheet metal cover - to protect students from moving parts. The cover should be made to fit over furnace blower pulley system. The size and shape will vary depending on the style of the blower.
D	*	Base - made of a piece of plywood or particle board, 3/4" x 15" x 61"
E		Two 2" x 4" x 47" bottom spacers and supports. The blower used in the drawing has a 1 1/2" space below the blower opening. Two spacers were needed to force the airflow directly onto the test vehicles in the tunnel. Procedures for constructing the bottom of the wind tunnel: - Plane down each board so a 1/4" piece of masonite can set on top of the bottom supports and line up with bottom edge of the blower opening. - Line up each board to fit in the space below the opening. Adjust the boards so they are parallel to each other. - The distance from the outside edge of the board to the outside edge of the other board should be approximately 10 1/2". - Using wood screws, fasten the two boards to the base.
F	*	Wind tunnel floor - cut a piece of 1/4" masonite 10 1/2" wide x 47" long. Place the masonite on the top of the 2 x 4 supports and fasten it into place.
G	*	Front section top - 1/4" piece of masonite, cut to 12" x 12"
H	*	Front section sides - 2 pieces of plywood or particle board, cut to 8 3/4" x 12" Locate and fasten parts G and H as shown in DR #1.
I	*	End section top - 1/4" piece of masonite, cut to 12" x 12"
J	*	End section sides - 2 pieces of 3/4" plywood or particle board, cut to 8 3/4" x 12". Locate and fasten parts I and J as shown in DR #1. This should leave approximately 22" for the test compartment area.
K	*	Front air flow inserts - 1" x 1" squares made out of poster board to fit the opening - NOTE: Paper towel tubes can also be used as the air flow inserts.
L	*	End air flow inserts - 1" x 1" squares made out of poster board to fit the opening - NOTE: Paper towel tubes can also be used as the air flow inserts.
M	*	Test chamber top - 1/4" Plexiglass cut to 12" x 24" NOTE: Make the Plexiglass top 2" bigger than the test chamber opening. In order to be able to fasten it to the end section, drill pilot holes in the Plexiglass and fasten it to the top of the wind tunnel.
N	*	Test chamber sides - Two pieces of 1/4" Plexiglass cut to 9" x 24". Drill pilot holes in one piece of Plexiglass and fasten to the back side of the wind tunnel. This side will be used for viewing only. The front will be hinged so the test vehicles can be taken in and out. To keep the test chamber opening closed, attach a Velcro strip around the edge.
O	*	Hinges for test chamber door
P	*	Cabinet door knob
Q	*	Single pole/single throw switch to control the motor

PRINCIPLES OF FLIGHT

Introduction

The purpose of this lab activity is to allow students to learn about how a heavier-than-air craft flies and can be controlled through an activity involving model aircraft construction and testing. In addition, students will experience aircraft control principles by making computer simulated models respond to different control input and through the use of a microcomputer aircraft flight simulator.

Materials and Supplies

Working individually, students will need the following items:

* 1 "Whitewings" student paper airplane kit
* scissors
* glue
* ruler
* paper clips
* rubber ban launcher

OPTIONAL MATERIALS
* Flight simulator computer program (e.g., flight simulator, glide path, radio-control airplane)
* Access to at least one microcomputer compatible with the flight simulator program

Activity Procedure

1. Assemble your model paper airplane according to the assembly instructions.

2. Using information provided by the instructor, perfect the model to achieve a smooth level flight. You should be able to fly the model straight and level at least three times in a row.

3. Identify the control surfaces of an aircraft and cut those areas on your model so flight control can be achieved.

   _____ controls roll

   _____ controls pitch

   _____ controls yaw

4. Practice flying your model by adjusting control surfaces to control the direction your plane flies until you feel comfortable being able to control the plan within parameters specified for a flight contest.

Activity Analysis

1. What forces allow a heavier-than-air object to fly?

2. What three axis does an aircraft rotate under?

3. How efficient is air transportation as a mode of mass transit?

Hypothesis

1. Most modern flight instructors attribute the force of lift on the aircraft wing primarily to _____.

   A. Bernoulli
   B. Newton
   C. Einstein

2. If the wing angle of attack is increased too greatly the plan will lose lift and _____.
   A. speed up
   B. bank
   C. stall

ROTARY-WING AIRCRAFT

Introduction

The quest for flight has intrigued humans for many centuries. At the present time, there are two common methods which human beings use to fly. Vertical takeoff and landing vehicles and horizontal takeoff and landing vehicles.

Vertical takeoff and landing vehicles, such as helicopters, are an extremely versatile and important form of air transportation. The most important advantage of helicopters is that they can ascend vertically into and out of small areas.

Helicopters are often used for rapid passenger transport between airports and city centers. Once in the city, helicopters often land at heliports on top of buildings. Helicopters have some special uses for which no other machine would be suitable. Only helicopters can be used for search and rescue work; for example, to rescue sailors from shipwrecks, to lift people trapped in burning buildings, or to remove people marooned by floods or earthquakes. Helicopters are used to move materials and workers to remote areas, and as sky cranes to hoist heavy objects to high places. Many times ski lift towers and high-voltage electrical towers are set in place by helicopters.

The upward force that pulls a helicopter into the air is called lift. Lift is created by the helicopter's rotors, or rotating wings. The rotors can be adjusted to increase or decrease their angle or pitch. By increasing the pitch, the rotor will increase the lift produced, and the helicopter will rise. Conversely, decreasing the pitch will decrease the lift and the helicopter will descend. The rotor unit is tilted by the pilot to steer the vehicle in the desired direction.

Advantages of Vertical Takeoff and Landing vehicles are:

* Ascend and descend vertically.
* Quick takeoff and landing ability.
* Can maneuver into small spaces.
* Good for search and rescue operations.
* Can aid construction in high places.

Disadvantages of Vertical Takeoff and Landing vehicles are:

* Their use is limited during inclement weather.
* They are expensive.
* Pilot training is long and expensive.
* Accidents are almost always fatal.

Materials and Supplies

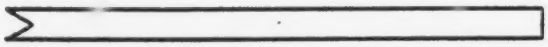
* Rubber Bands
* Plastic Propeller set up (Midwest Products Co., Inc., 400 S. Indiana St., PO Box 564, Hobart, IN 46342, Phone (219)942-1134)
* 1/2' X 1/8" X 6" balsa wood strips (fuselage)
* File folders or 3/16" cardboard (i.e. Note pad backing)
* Scissors
* Stapler
* Pen or pencil

Problem Statement

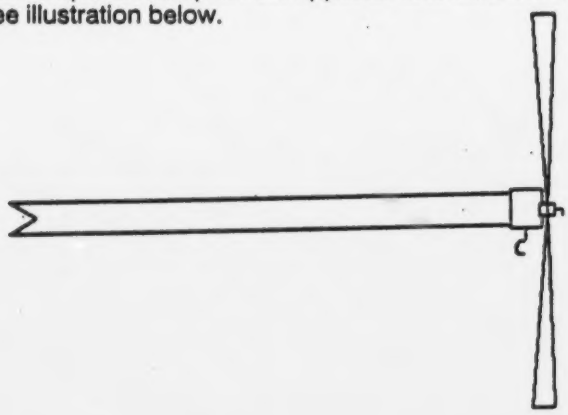
Using the materials provided, design and build a simple rotary-winged aircraft. After completing the aircraft, test it to check for balance and design defects. If the aircraft shows signs of defects, such as fuselage rotation or rising on an angle, explain why the vehicle reacted in this manner.

Activity Procedure

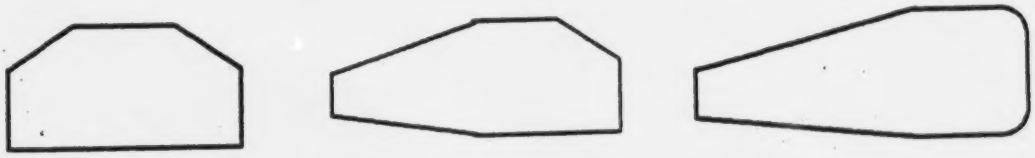
1. Obtain the needed materials from your instructor.
2. Cut a V-groove in one end of the 1/2' X 1/8" X6" balsa wood strips to be used as fuselage. See illustration below.



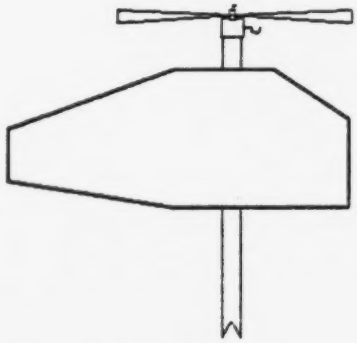
3. Assemble the Plastic Propeller set up on the opposite end from the V-grove of the balsa wood fuselage. See illustration below.



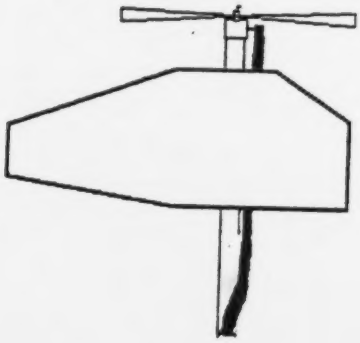
4. Draw several shapes of the stabilizer on either the poster board or the file folder material and cut the shape using the scissors. See examples below.



5. After cutting several shapes, attach one of the shapes to the balsa wood fuselage. See illustration below.



6. Place a rubber band on the loop of the propeller set up, stretch it and place it in the V-grove of the fuselage. See illustration below.



7. You are now ready to test your rotary-winged aircraft. Grasp the balsa wood fuselage at the V-groove end with your left hand. With your right hand, turn the propeller to twist the rubber band. This will provide power to the aircraft. NOTE: Be sure to turn the propeller in a direction as to provide lift. To determine that you are turning the propeller in the right direction, turn it several times with your right hand. Release the propeller. If you feel the wind created by the propeller on your left hand, then you have turned the propeller in the right direction.

8. After determining the direction, wind the rubber band as tight as possible without breaking it. Hold the aircraft vertically. Let the propeller rotate under its own power for a split second before releasing the aircraft.

9. Repeat this process for three different aircraft designs.

Activity Analysis

1. Observe the behavior of each aircraft design and record the following information:

   A. Sketch the shape of the aircraft design.

   B. Did the aircraft rise from the release point?

   _____

   C. Approximately how high did it rise? _____

   D. Did the aircraft maintain a vertical lift?_____
   If not, explain why.

   _____

   _____

   _____

   _____

   E. Did the fuselage of the aircraft rotate around?_____
   If so, explain why.

   _____

   _____

   _____

   _____

LIGHTER THAN AIR VEHICLES

Introduction

People have long dreamed of flying and have tried a wide variety of astounding methods in their attempt to emulate birds. Many different means were tested, but it was not until 1783 that humans actually became airborne.

In that year, the Montgolfier brothers in France made their first trip in a lighter-than-air balloon. The aircraft was made of linen, was filled with heated air from burning straw, and was considered a real vehicle to carry persons.

On January 17, 1785 an Englishman named Blanchard piloted a hydrogen filled balloon across the English Channel. This flight is noteworthy for two reasons: 1) first passenger, an American, Dr. T. J. Jefferies, 2) first carrier of international mail on record. Eight years later, Blanchard brought his balloon to the United States for demonstrations in Philadelphia, where President George Washington was a spectator.

A balloon floating free in the air senses no wind and no air forces except the dynamic effects of turbulence; it rides with the wind as part of the air mass. Some limited navigation can be accomplished by dropping a ballast or by valving gas to descend into layers of wind blowing in different directions. A drag rope can be dragged over the ground, helping to stabilize the balloon at low altitudes and slow it down. Skill and experience are required to land a balloon smoothly.

There are approximately 5,000 active certified balloon pilots flying about 3,700 hot-air and gas balloons in the United States today. Some recent landmarks include; 1) crossing the Pacific Ocean by Ben Abruzzo in his Double Eagle V in 1981, 2) a solo flight across the Atlantic Ocean by Joe Kittinger, aboard his 10 story high Rosie O'Grady's balloon, in September 1984, and 3) record Atlantic crossing of 51 hours by 3 Dutch balloonists in September of 1986.

Today, balloons are used regularly by the National Weather Service. These balloons are equipped with radiosonde, an instrument package that sends back readings as it rises through the atmosphere.

The following concepts must be understood by the ballooning hobbyist:

1. Pilots are licensed aeronauts.
2. Balloons and associated equipment weighs over 300 pounds.
3. The investment cost is $5,000 plus.
4. Balloons have right of way in the air corridors.
5. Launch envelope is best at sunrise and when heavy winds are not present.
6. The parts of a balloon include the gondola used to carry passengers, burner, using propane fired-up to 250 degrees F. to raise the balloon, and an envelope made of taffeta weave nylon.
7. Balloons can ascend or descend 300 feet per minute
8. Wind currents give the balloon direction.

Materials and Supplies

* Tissue paper
* Scissors
* 2 Sterno cans (7 oz.)
* Rubber cement
* Masking tape
* 1 - 6" x 24" Stove pipe
* 9 fire brick
* Filmstrip & cassette projector
* Tin snips
* Leather gloves

Problem Statement

In this activity, you will build a lighter-than-air vehicle. By doing so, you will be exposed to the concept of how heat rises, weather turbulence, and atmospheric pressure. This lighter-than-air vehicle will be designed and flown with the use of heat.

Activity Procedure

1. Building the lighter-than-air vehicle.

   A. Always review all material that was given to you by your instructor.
   B. Locate all materials that will be needed to complete the activity. They are:

Tissue paper	Masking tape
Scissors	1 - 6" x 24" stove pipe
Two Sterno cans, 7 oz.	9 fire brick
Rubber cement	Tin Snips
Leather gloves	

   C. Start by building the lighter-than-air vehicle first. Lay out eight pieces of tissue paper (20" x 25") on a large working surface.

   D. Using the rubber cement, glue two pieces of the tissue paper together to form a single piece that is 50" long x 20" wide. Complete this process with the other six sheets of tissue paper.

   E. Make a 1/4" fold on the long sides (50") of the tissue paper. This will be used for gluing.

   F. Use the rubber cement to glue the edges of the tissue paper to form a large box.

   G. While this box is drying take four pieces of tissue paper and cut them to the size shown on DR #1, Diagram A.

   H. Make a 1/4" fold on the hypotenuse size of the four pieces of tissue paper.

   I. Use the rubber cement to glue the four pieces into a box.

J. Now glue the two boxes together to form the lighter-than-air vehicle (DR #1, Diagram B).

K. Use the flat piece of tissue paper and cut it to a 20 1/2" x 20 1/2" square. This will make the top of the vehicle.

L. Make a 1/4" fold on all four sides of the top.

M. Use the rubber cement to glue the top on the vehicle (an extra set of hands from a friend will help).

N. Use masking tape to form the bottom of the vehicle. Hold it over the 6" diameter stove pipe and tape around the bottom edge. Keep the bottom loose so that it may slide up and down on the 6" stove pipe.

O. Using tin snips, cut a semi-circle at only one end of the 6" stove pipe (as shown in DR #2, Diagram C).

P. Form a chimney using the nine fire bricks and set the stove pipe over the brick to form the chimney (DR #2, Diagram D).

Q. Place the sterno cans on the floor and, using matches provided by your instructor, light the heating source.

R. With the two stern cans placed under the chimney, hold the lighter-than-air vehicle over the chimney and allow the hot air to fill the balloon. NOTE: A fan may be needed to force the hot air up in the balloon. Be careful not to touch the stove pipe without the leather gloves.

S. When the balloon is filled, release it and see if it will touch the ceiling.

T. With your instructor, discuss why the balloon goes up and down.

U. Reduce the fire brick so that only three are used to form the chimney.

V. Repeat the process and explain to your instructor what happened and why.

W. Clean up the laboratory. Remember the stove pipe is hot and needs to cool before storing.

Activity Analysis

Based on the experience gained during the activity:

1. What is the relationship between the volume of air in the balloon and the payload to be carried?

_____

_____

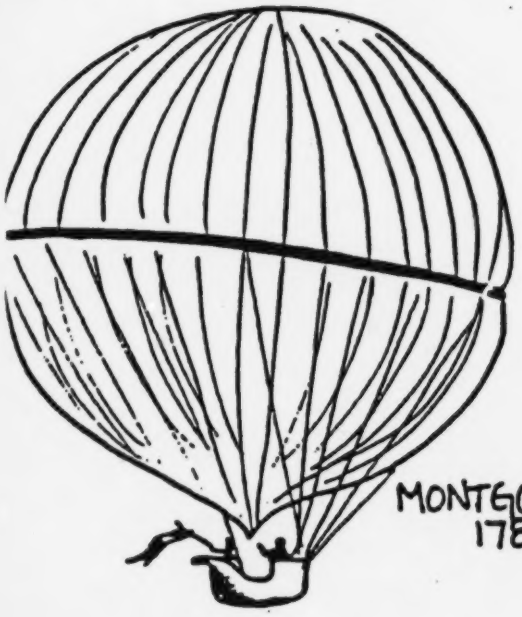
2. What are potential uses for lighter-than-air vehicles?

3. What are the advantages of lighter-than-air vehicles?

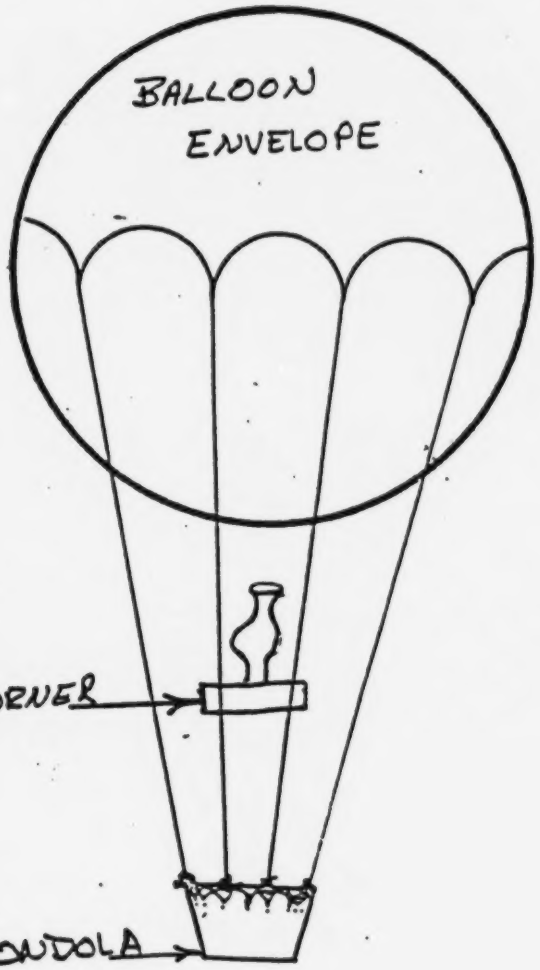
4. What are the disadvantages of lighter-than-air vehicles?

LIGHTER-THAN-AIR CRAFT

EARLY AVIATION



MONTGOLFIER BROTHERS
1783 (FRANCE)



LIGHTER-THAN-AIR-VEHICLE

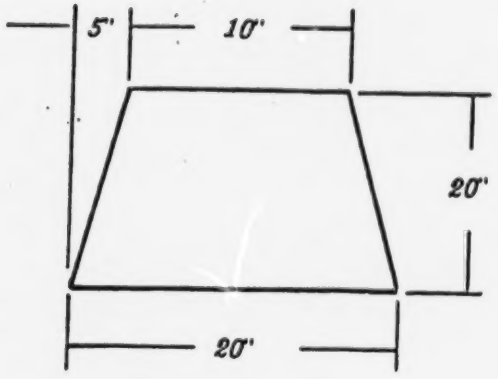


Diagram A

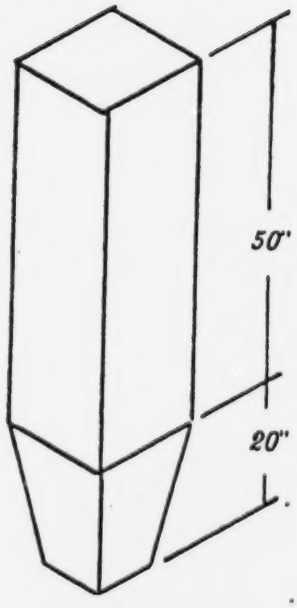


Diagram B

20-A

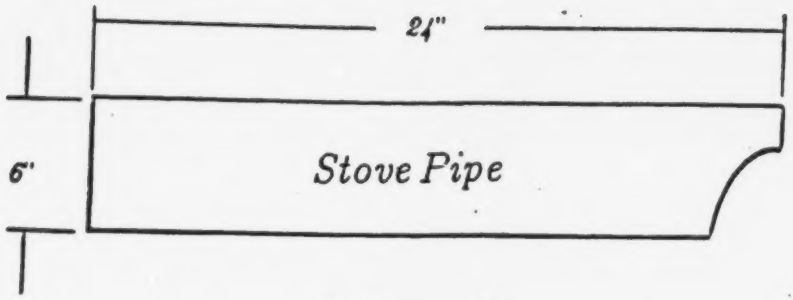


Diagram C

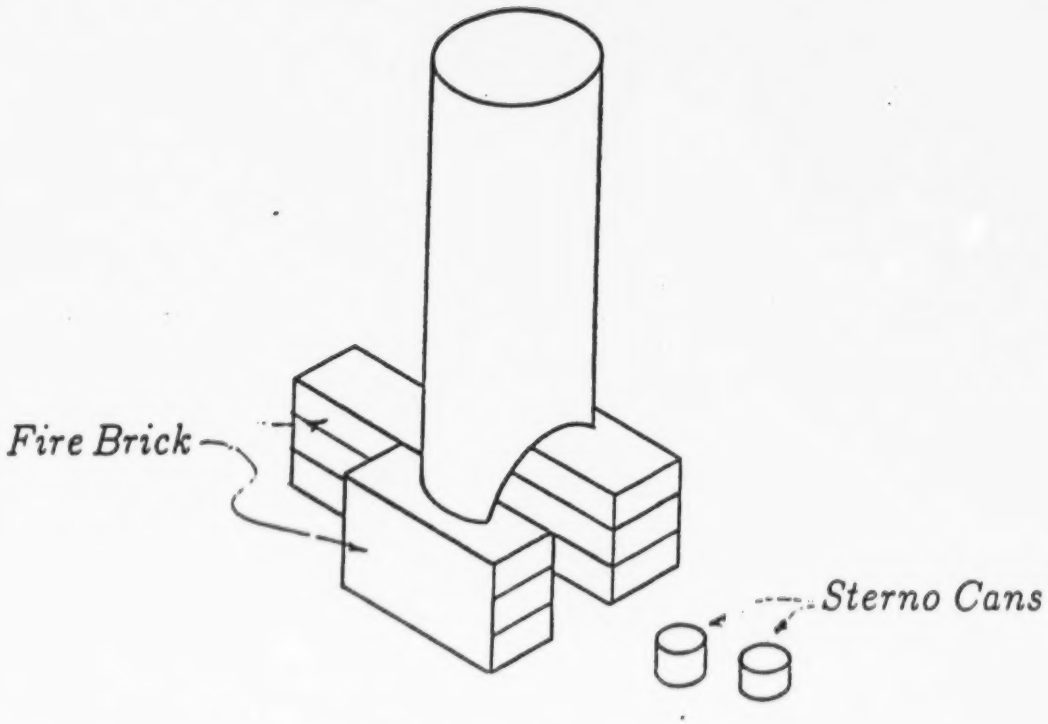


Diagram D

SPACE TRANSPORTATION TECHNOLOGY

SPACE TRANSPORTATION SYSTEMS

Suggested Learning Objectives

Upon completion of the Space Transportation Technology unit, students will be able to:

A. Define and properly use common space transportation **terminology** like lunar module, command module, deceleration, tether, flight trajectory, pitch, yaw, perigee, suborbital, jettison, escape velocity, cosmonaut, airlock, insertion burn, refurbished, and geosynchronous.

B. Identify the basic **applications** for space transportation including things like deploying communication satellites, collecting scientific data, conducting experiments in space, and exploring the other galaxies.

C. Describe the societal and environmental **impacts** associated with space transportation activities like the creation of new technologies, improving international communication systems, space pollution, and utilization of financial, human, and material resources. SC2

D. Describe the **processes** used in space transportation like launching, docking, landing, exploring, stabilizing, deploying, staging, descending, accenting, orbiting, and recovering.

E. Describe the basic human, material, natural, informational, financial, and technological **resources** associated with space transportation processes and enterprises (e.g., mission specialists, liquid hydrogen, federal funding).

F. Describe the major milestones in the **history** and evolution of space transportation technology including the development of the first liquid fueled rocket by Dr. Goddard; the launching of Sputnik I in 1957; the accomplishments made by the Mercury, Gemini, and Apollo projects; the information gathered by the Mariner, Pioneer, and Viking deep space probes; the impact of the space shuttle disaster; and the conceptualization of orbiting space stations. SS2

G. Identify, describe, and evaluate **career** opportunities related to space transportation technologies (e.g., mission specialist, aerospace engineer, astronomer) based on their interest, talents, and career expectations.

H. Identify potential **safety** hazards, establish guidelines for safe behavior, and adhere to common safety practices when making, testing, launching, and recovering model rockets around or participating in space transportation activities.

I. Describe the basic payload, guidance, propulsion, control, and support systems for a given mode of space transportation.

J. Design, build, and test a working model space transportation system that features a propulsion, control, guidance, payload, recovery, and support systems.

K. Use common tools, materials and techniques to design, build and test model space transportation systems; to collect and interpret data; and to simulate space travel.

L. Describe the advantages and disadvantages of various types of space transportation vehicles including rockets, space probes, and space shuttles. SC2

M. Evaluate the pros and cons associated with the exploration and development of space for scientific, military, and commercial applications. SC2

N. Forecast the role of space transportation in the development of futuristic manufacturing, communication, construction, transportation, and energy utilization technologies. SC2

O. Explain and demonstrate how scientific concepts like gravity, potential energy, kinetic energy, and Newton's third law of motion apply to rocket engines and space transportation systems. SC1

P. Use a variety of mathematical principles and techniques to determine the relationship between variables like weight, velocity, attitude, and thrust. MA4

Suggested Learning Experiences

1. Introduce students to basic propulsion, control, and payload systems on various kinds of space vehicles. Using commercial and/or constructed components (e.g., body tube, fins, nose cones, streamers), have students design and build model rockets. Each design should include things like a payload cavity, a recovery system, tuned fins, an engine mount, and identification markings. Have students compare and contrast the propulsion, control and payload system on their rocket with those on real rockets. Ask students to describe how rocket designs have changed over the years and how space vehicles might look in the future.

2. Discuss the techniques to be used to test rockets and their components. Have each student test the stability of their rocket by attaching a string to its center of gravity and swinging the rocket overhead in a circular path. Have students modify unstable rockets by enlarging fins or adding weight to nose cones. Consider using a commercial or constructed wind tunnel to conduct additional tests. Ask students to explain why quality control and tests are so important to space transport technology.

3. Introduce students to the procedures used to launch space vehicles. Have each student design and complete a pre-launch check list. The check list should include things like safety procedures, rocket components, launch area specifications, engine requirements, and weather conditions. When the rocket has completed the pre-launch procedures in a large open area, have the students conduct countdown procedures and launch model rockets. Discuss how automated systems are used to monitor pre-launch procedures of real rockets.

4. Discuss how rockets are tracked during space missions. Using a commercial or constructed tracking device, and a teacher prepared worksheet, have students measure the angle between launch pad and the rocket's peak altitude from a given base line distance. Using the data collected, have students calculate the altitude achieved by their rocket. Have students discuss the consequences of a poor tracking system on crew safety and future missions.

5. Explain why space vehicles use staging to overcome the forces of gravity and achieve an orbit. Discuss how space vehicle design and propulsion systems are influenced by their applications. Have students weigh their rockets, launch their rockets using a small engine, track their rockets' flight, and determine the altitude achieved. After recovering their rocket, have them repeat the procedure using a larger engine. Have students determine the relationship between engine thrust (size), the vehicle and payload weight, and vehicle's altitude and flight duration.

6. Explain how computer simulations are used to test space flight procedures and train astronauts and mission specialists. Discuss how computers are used to monitor and control space vehicles. Using one of the popular computer simulation programs, have students conduct a simulated space flight. Each space flight should include things like launching a vehicle, establishing an orbit, docking with a space station, retrieving or deploying satellites, and conducting re-entry and recovery procedures. Ask students to describe the impact of computer technology on the development and implementation of space transportation systems.

7. Discuss how a lunar rover was used to explore the surface of the moon. Using materials like hobby motors, photovoltaic, model car wheels, and batteries, have students design, build, test, and present a model lunar vehicle. Each presentation should include an explanation of the vehicle's communication, life support, propulsion, control, and payload systems. Ask students to discuss how lunar vehicles can effect things like mission flexibility and duration.

8. Discuss the milestones in the history and evolution of space transportation technology. Assign each student a historical event. Using library resources, have students gather information and develop an abstract describing the people, dates, places, and impacts associated with their assigned event. Encourage students to illustrate their abstracts. Post each abstract on a large timeline. Ask students to describe how given events influenced our culture and subsequent technological developments.

9. Discuss the career opportunities in space transportation technology. Include occupations at the non-skilled, semi- skilled, skilled, technician, and professional levels in the discussion. Using library and guidance resources, have students gather information and present a short written or verbal report about an occupation related to space transportation technology. Each report should include information about the educational requirements, working conditions, benefits, salary, and advancement potential related to the occupation. Ask students to evaluate the career based on their interests, talents, and career expectations.

SPACECRAFT DESIGN

Introduction

The purpose of this activity is to acquaint students to rocket design principles, flight characteristics, payload systems, and rocket stability and safety. Participants will learn by designing, building, testing, and launching a rocket of their own design. This activity will give students insight into space travel and spacecraft design.

Materials and Supplies

For the construction activity, small groups can be used to keep cost down or students can each construct their own rocket. Groups of two seem to work best on the computer interaction.

* One designer rocket parts kit for each five students or groups (rockets could also be made from scrap material or purchased materials)
* White glue (fast drying super glue)
* Hobby knives
* Wind tunnel
* Launch pad and launch control system
* Protractor
* Balance beam scales
* Rocket engines
* Sandpaper
* Paint

OPTIONAL MATERIAL

* Computer simulation software (e.g., Model Rocket Design, Rocket Flight Production by Estes, Principles of Flight, Physics of Rockets, Rendezvous, Space Max)
* Apple II series computer with one disk drive and monitor

Problem Statement

NASA is looking for a new launch vehicle for its satellite program. Since the Challenger disaster, foreign space companies like France and Japan have taken over the market. NASA wants your company to design a new rocket. The ability of the United States to reenter the space race depends on the success of your design. Each design presented must contain a parts list, design drawing (front and side views), pass both the string and wind tunnel test, and complete a successful flight.

Activity Procedure

1. Look through the material provided in the designer rocket parts kit.

2. Using a computer and the popular computer simulated program, (e.g., Model Rocket Design, design a rocket that will accommodate the materials provided (Designer Rocket parts kit).

3. Based on the experience gained through the computer simulation, refine your design using grid paper.

4. You may design your rocket as you see fit, as long as the kit contains the materials. Be sure to consider the task the rocket must perform (fly stable and return back to earth) and the limits of the test wind tunnel when considering your design.

5. Based on your design, carefully construct the model rocket.

6. After assembling your rocket, locate the center of gravity by balance method. (See Testing Rockets for Stability Activity).

Activity Analysis

1. Why must a rocket be stable to fly correctly?

2. Does a rocket accelerate straight up when attempting to reach an orbit?

3. What problems must be considered when designing recovery systems?

Hypothesis

Stability of a rocket is dependent on two characteristics. What are they?

1. _____

2. _____

TESTING ROCKETS FOR STABILITY

Introduction

In order for a rocket to fly, it must be stable. If the rocket is stable, it will travel with the nose pointing in the same direction throughout the flight. To understand how to stabilize a rocket, you must understand the terms "center of gravity" (CG) and "center of pressure" (CP). The center of gravity is the point on a rocket where it is balanced. The center of pressure is a point on the rocket where all the forces of the air act on it. The center of pressure can be affected by fin shape, size, number, and location. Center of pressure can also be affected by the rocket's body design and nose cone shape. For a rocket to be stable, the center of pressure **must be behind** the center of gravity. If the center of pressure is in front of the center of gravity, the rear of the rocket will try to roll forward, thus, causing the rocket to roll out of control and crash. The center point of pressure can be moved to the back of a rocket by adding weight to the nose and moving the fins toward the rear. You can also move the weight backwards by enlarging the fins. This will also cause the center of gravity to move toward the front.

This Technology Education Activity is designed to complement a model rocket design activity. In this activity, students will test the stability of model rockets by running them through a series of tests.

Materials and Supplies

* Model rocket
* Access to a wind tunnel (DR #1)
* At least six to ten feet of kite string
* Masking tape
* Felt marker
* Hand-held wind speed indicator

Problem Statement

Since the Challenger Space Shuttle disaster, rocket design has been a hot issue. As a member of the research and development department for a rocket manufacturer, you are responsible for testing the stability of new designs. Your company is in the process of developing a new launch vehicle for deploying commercial satellites. Recently, a new design has been brought to your department for testing. It is up to your department to determine if the new design is stable. If the rocket design is flawed or fails to pass the test, your test team must provide design modifications which will correct the problem. The space program can not afford another major disaster. It is up to your team to decide whether the new design will fly safely.

Activity Procedures

Testing Stability Using the String Method

1. One of the first steps is to determine the rocket's center of gravity. This can be done by tying a loop in one end of the kite string. Loop the string over the nose of the rocket. With the engine installed, balance the rocket. Use the marker to mark the location. Then, carefully tape the string in place.

2. Once the center of gravity has been located, the next step is to conduct the test. Make sure you have plenty of room. With the string securely in place, swing the rocket in a circular motion around your head. NOTE: The longer the string, the more accurate the test. If the rocket continues to point forward, the rocket is stable. If the nose begins to point in any other direction, the weight of the rocket must be moved forward. For an added measure of safety, move the center of gravity back so that the nose of the rocket tips down ten degrees below the horizontal. Then repeat the test. If the nose of the rocket continues to point forward, the design should be safe enough to launch.

Testing Stability Using a Wind Tunnel

1. The stability of a rocket can also be tested in a wind tunnel. The first step is to determine the rocket's center of gravity. This can be done by tying a loop in one end of the kite string. Loop the string over the nose of the rocket. With the engine installed, balance the rocket. Using a felt marker, mark the center of gravity. Carefully draw a line around the rocket.

2. Once the center of gravity has been marked, prepare the wind tunnel. Adjust the blower pulleys to produce an airflow of about thirty to fifty miles per hour.

3. With the blower turned off, place the rocket into the wind tunnel.

4. Position the rocket in the wind tunnel as shown in DR #1. Make sure the rocket is secure.

5. Carefully turn on the blower. If the rocket continues to face forward, the design is stable. If the nose of the rocket fails to maintain its forward position, then the design is flawed.

6. For added safety, move the center of gravity back so that the nose of the rocket tips down ten degrees below the horizontal. Then, repeat the test. If the nose of the rocket continues to point forward, the design should be safe to launch.

Activity Analysis

1. Based on your test results, which one of the following recommendations will your test team present to management?

   a. Scrub the mission and start a new design.
   b. Modify the existing design and then retest.
   c. The design is okay. Prepare the rocket for launch.

If your team selected option b, what design modifications do you recommend to stabilize the rocket and make it safe to fly.

_____

_____

2. What are the potential consequences of launching a rocket that is unstable?

_____

_____

3. A rocket becomes unstable when

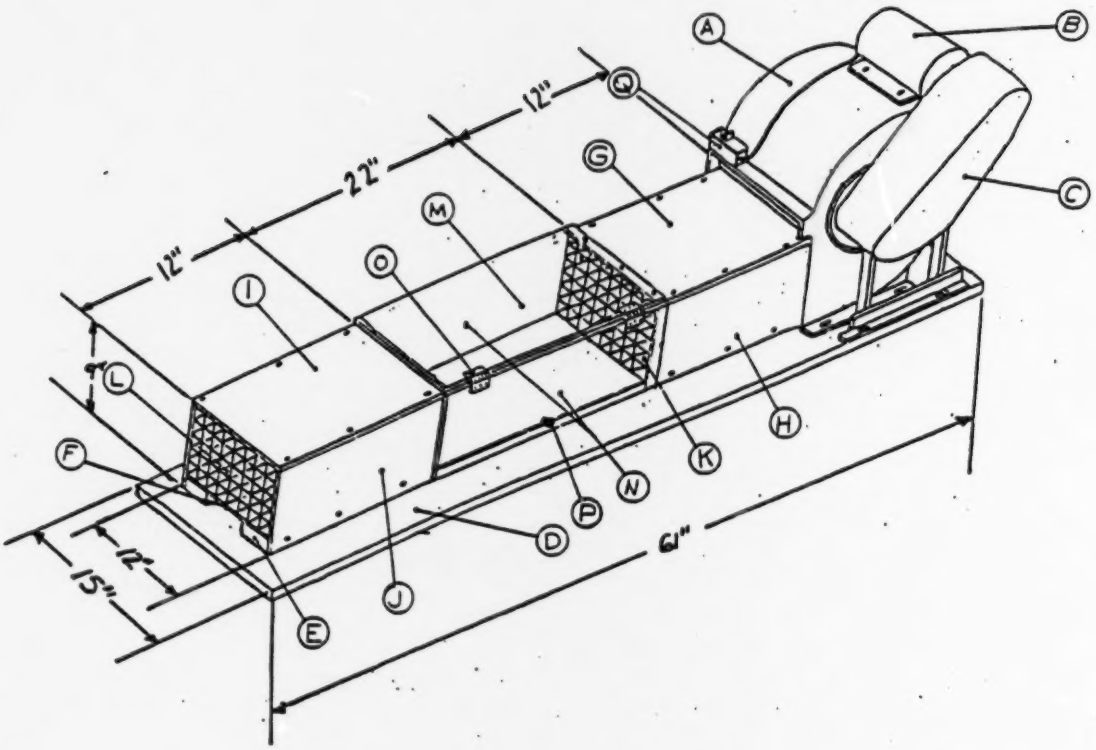
   a. the center of pressure and the center of gravity are equal.
   b. the center of pressure is in front of the center of gravity.
   c. the center of pressure is behind the center of gravity.

4. If a rocket is unstable, which of the following will help correct the problem?

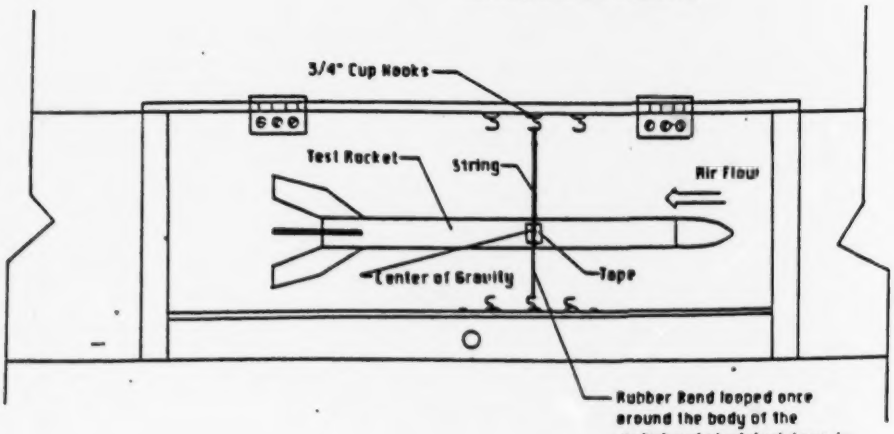
   a. Position the fins higher.
   b. Decrease the weight of the nose cone.
   c. Decrease the size of the fins.
   d. Add weight to the nose of the rocket.

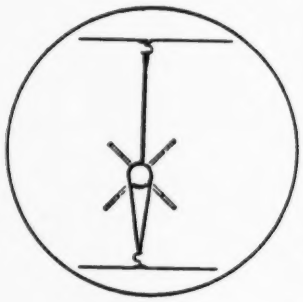
Wind Tunnel

DR #1



Test Chamber Detail
Testing Rocket Stability


3/4" Cup Hooks
Test Rocket
String
Air Flow
Center of Gravity
Tape
Rubber Band looped once around the body of the rocket and stretched down to the cup hook. The will help keep the rocket in place during the test.



Test Stand Details

3/4" cup hooks positioned in several places to allow for different styles of rockets and different centers of gravity. The cup hooks should be located down the center of the top and bottom of the test chamber. Loop a piece of string over the rocket and tape it at the center of gravity. Attach the other end of the string to one of the cup hooks at the top of the test chamber. Then loop a rubber band around the rocket and stretch it down to a cup hook at the bottom.

BILL OF MATERIALS FOR A FURNACE BLOWER WIND TUNNEL

PART		DESCRIPTION & PROCEDURES
A	*	Furnace blower - NOTE: **The actual construction of your wind tunnel may vary from the process described below due to the various styles of furnace blowers available.**
B	*	Furnace blower motor
C	*	Sheet metal cover - to protect students from moving parts. The cover should be made to fit over furnace blower pulley system. The size and shape will vary depending on the style of the blower.
D	*	Base - made of a piece of plywood or particle board, 3/4" x 15" x 61"
E		Two 2" x 4" x 47" bottom spacers and supports. The blower used in the drawing has a 1 1/2" space below the blower opening. Two spacers were needed to force the airflow directly onto the test vehicles in the tunnel. Procedures for constructing the bottom of the wind tunnel: - Plane down each board so a 1/4" piece of masonite can set on top of the bottom supports and line up with bottom edge of the blower opening. - Line up each board to fit in the space below the opening. Adjust the boards so they are parallel to each other. - The distance from the outside edge of the board to the outside edge of the other board should be approximately 10 1/2". - Using wood screws, fasten the two boards to the base.
F	*	Wind tunnel floor - cut a piece of 1/4" masonite 10 1/2" wide x 47" long. Place the masonite on the top of the 2 x 4 supports and fasten it into place.
G	*	Front section top - 1/4" piece of masonite, cut to 12" x 12"
H	*	Front section sides - 2 pieces of plywood or particle board, cut to 8 3/4" x 12" Locate and fasten parts G and H as shown in DR #1.
I	*	End section top - 1/4" piece of masonite, cut to 12" x 12"
J	*	End section sides - 2 pieces of 3/4" plywood or particle board, cut to 8 3/4" x 12". Locate and fasten parts I and J as shown in DR #1. This should leave approximately 22" for the test compartment area.
K	*	Front air flow inserts - 1" x 1" squares made out of poster board to fit the opening - NOTE: Paper towel tubes can also be used as the air flow inserts.
L	*	End air flow inserts - 1" x 1" squares made out of poster board to fit the opening - NOTE: Paper towel tubes can also be used as the air flow inserts.
M	*	Test chamber top - 1/4" Plexiglass cut to 12" x 24" NOTE: Make the Plexiglass top 2" bigger than the test chamber opening. In order to be able to fasten it to the end section, drill pilot holes in the Plexiglass and fasten it to the top of the wind tunnel.
N	*	Test chamber sides - Two pieces of 1/4" Plexiglass cut to 9" x 24". Drill pilot holes in one piece of Plexiglass and fasten to the back side of the wind tunnel. This side will be used for viewing only. The front will be hinged so the test vehicles can be taken in and out. To keep the test chamber opening closed, attach a Velcro strip around the edge.
O	*	Hinges for test chamber door
P	*	Cabinet door knob
Q	*	Single pole/single throw switch to control the motor

LUNAR ROVER

Introduction

The potential exploration of the moon's surface has captured people's imagination for centuries. The first wheeled vehicle to operate on the lunar surface was launched by the Soviet Union on November 10, 1969. This vehicle, called Luna 17, carried Lunokhold I (Moon Rover). This solar powered eight-wheeled vehicle was the size of a small car. There was no crew aboard this vehicle and it was guided by a 12-man crew here on earth. The Lunokhold I scooped up samples of surface matter, analyzed them, and relayed the information back to earth.

The United States began using a lunar rover with the Apollo 15 mission launched from Cape Kennedy on July 26, 1971. The first men to operate a lunar rover on the surface of the moon were astronauts Scott and Irwin. Traveling a total of 45 miles in the lunar rover (Moon buggy), they collected rock and soil samples, took photographs, and described the lunar terrain. The mission collected 35 pounds of lunar rock samples. Apollo 16 and 17 also carried a lunar rover to the moon and, again, the astronauts used the "rover" for scientific experiments and collecting lunar samples. All three rovers are still on the moon.

The lunar rover looked like a stripped down dune buggy, slapped together from odds and ends (TA #1). Designated Lunar Roving Vehicle (LRV) and nicknamed Rover, it had no steering wheel or brake pedal. The steering was controlled by manipulating the front and back wheels. The Rover could travel either forward or reverse at speeds of nearly 10 mph. Small 1/4 horsepower electric motors in each wheel hub provided power. Each pair of motors was powered by two 36 volt electric batteries.

The Rover design enabled it to cross 2 foot wide crevasses and climb slopes as steep as 25 degrees. On earth, the rover weighed 455 pounds, but on the moon with 1/6 the gravity field of earth, it weighed only 76 pounds. Its sturdy design, built by Boeing, enabled it to carry two and one-half times its own weight. When the day's work was done, Rover's computerized navigation system guided it unerringly back across the uncharted landscape to its lunar module base.

The addition of the lunar rover to the Apollo moon mission greatly extended the astronauts' potential to explore the moon. With plans for future space travel to other planets, Mars for instance, a lunar rover may once again be called upon for similar service. In this activity, your group will design, build, and test a lunar rover that will solve a given problem.

Materials and Supplies:

Since this is a problem solving activity, the materials you choose to use with your students may vary. The list below contains suggested materials.

- loose dirt
- weight scale (able to weigh 0-10 pounds)
- test track (DR #1)
- 1/8" or 1/4" grid paper
- hobby motors
- photovoltaic cells (3V-6V)
- flashing LED light
- bell wire
- an assortment of hobby-sized gears
- batteries (AAA and 9V)
- rubber bands (1/4" wide)
- soldering gun
- wood glue
- glue gun and glue sticks
- coping saw
- band saw
- hand drill or drill press
- hole saw
- sand paper
- straight pins
- spring clothes pins

Any or all of the following structural materials:

- 1/4" foam core cut to 3" x 10" pieces
- balsa wood strips, 1/8" x 1/8" x 24"
- balsa wood strips, 3/16" x 3/16" x 24"
- steel rod, 1/8" x 1/8" x 24"
- drinking straws
- tooth picks

Optional equipment and materials:

- film or video about the Lunar Rover for NASA
- movie projector or VCR and monitor
- a computer and monitor (to create project drawings or keep track of materials)
- a popular CAD software package
- a popular spreadsheet software package

Problem Statement

NASA has hired your company to design, build, and test a new lunar vehicle prototype. The new rover will be part of NASA's future missions to Mars. Since cost and safety are of great importance, your design must adhere to the following guidelines and specifications:

- The vehicle must weigh less than three pounds (not including a payload)
- The total length cannot exceed 9 inches (see Figure 1 below)
- The total height cannot exceed 2 3/4 inches (see Figure 1)
- The total width cannot exceed 4 inches (see Figure 1)

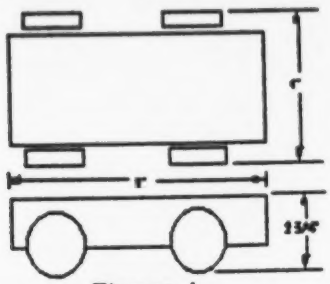


Figure 1

- The vehicle must travel at least twenty feet under its own power.
- The vehicle must be powered by solar and/or batteries.
- The vehicle must be able to carry three times its own weight.
- The vehicle must send a continuous signal.
- The vehicle must be able to travel up a 15 degree incline, drive through a stretch of gravel and dirt, and maneuver over three 1" cracks while carrying a payload.
- The total cost of the project must be less than $1,000,000.
- Each design submitted must include a set of drawings (e.g., front, top and right side views of the vehicle), detailed bill of materials (e.g., parts or supplies, quantity, date, price per unit, total price), and total cost of project.

Activity Procedure

1. Review all information presented by your instructor.

2. Obtain several sheets of plain white paper from your instructor. With the paper, make at least three rough sketches of your lunar rover design.

3. Select the design your group feels is the best.

4. Obtain a copy of the refined drawing handout from your instructor (SH #2). Make a final drawing of your vehicle. Be sure the drawing is neatly done and includes dimensions.

5. Acquire a materials and price list from your instructor (SH #3). Use your drawing and the price list to make an estimate of the cost of your vehicle design. What is the estimated cost of your project? _____

6. Using the bill of materials (SH #4), attain the materials needed to construct your vehicle. Be sure to keep accurate records of the materials, supplies, and equipment used by your group.

7. When your group has finished constructing the vehicle, test it on the track provided by your instructor. After the test, make modifications and refinements to the design.

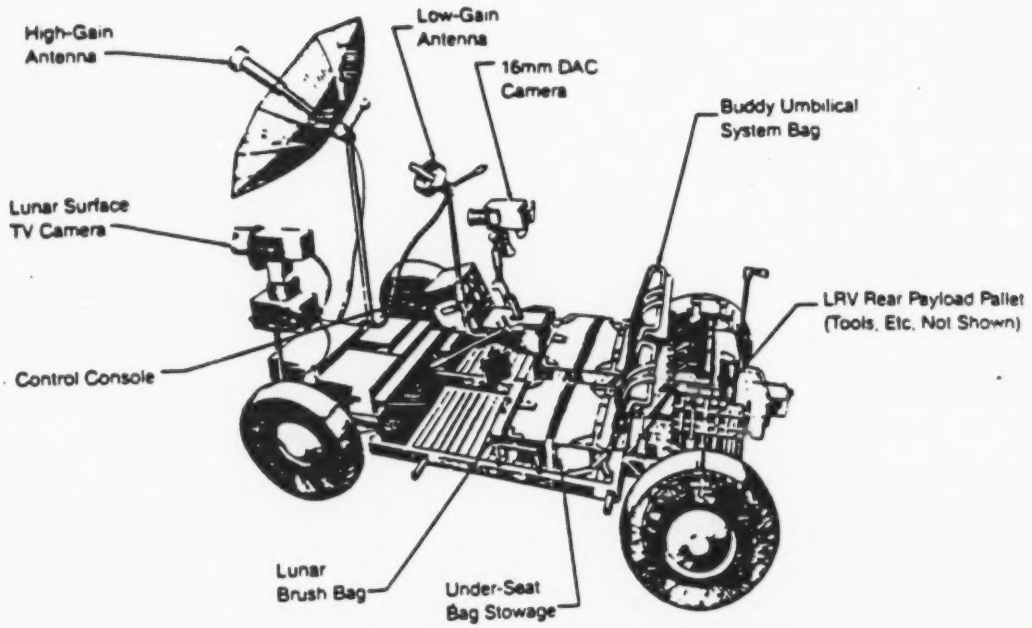
8. After changes have been made, calculate the final cost. What is the final cost of the project? _____ Compare the final cost to the estimated cost (see Step #5).

9. Conduct a final test for the class and your instructor.

10. After the test, submit your group's drawings, bill of materials, and lunar rover prototype.

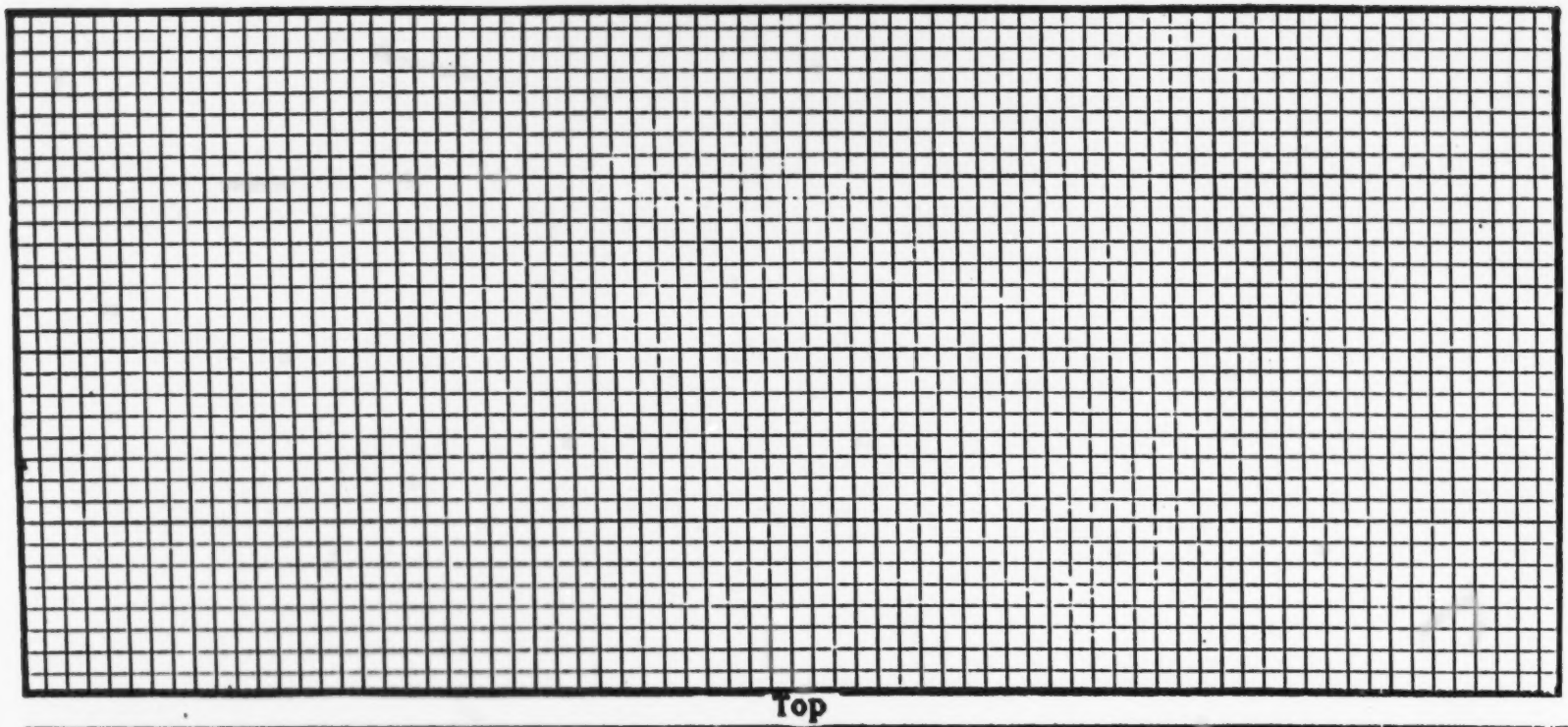
11. Clean up your group's work station and laboratory.

LUNAR ROVER



Picture taken from: DeOld, A. R., Sheets, E., Alexander, W. (1986). Transportation: The technology of moving people and products. Worcester: Davis. p. 427.

Refine Design Drawing Sheet



SH #2

EQUIPMENT AND SUPPLY PRICE LIST

- Weight scale		$1,000/use
- Test track use		1,000/test
- 1/8" or 1/4" grid paper for designing project		1,000/piece
- Pencil		1,000/day
- Hobby motors		50,000/unit
- Photovoltaic cells (3V-6V)		45,000/cell
- Bell wire		10,000/inch
- An assortment of hobby-sized gears		8,000/gear
- Batteries (AAA and 9V)	(AAA)	10,000/battery
	(9V)	30,000/battery
- Rubber bands (1/4" wide)		5,000/rubber band
- Soldering gun and solder		10,000/day
- Wood glue		10,000/2 oz.
- Glue gun		10,000/day
- Glue sticks		10,000/day
- Coping saw		10,000/day
- Band saw		10,000/day
- Hand drill or drill press		10,000/day
- Hole saw		10,000/day
- Sand paper, any grit (3" x 6")		5,000/piece
- Straight pins		1,000/pin
- Spring clothes pins		1,000/pin
- Flashing LED light		20,000/light
Any or all of the following structural materials:		
- 1/4" foam core cut to 3" x 10" pieces		50,000/piece
- Balsa wood strips, 1/8" x 1/8" x 24"		6,000/inch
- Balsa wood strips, 3/16" x 3/16" x 24"		10,000/inch
- Steel rod, 1/8" x 1/8" x 24"		12,000/inch
- Drinking straws		20,000/straw
- Tooth picks		10,000/tooth pick
- Legal and auditor fees for misuse of funds (.e.g, improper recording of bill of materials, using non-teacher approved materials, safety violations)		100,000/count

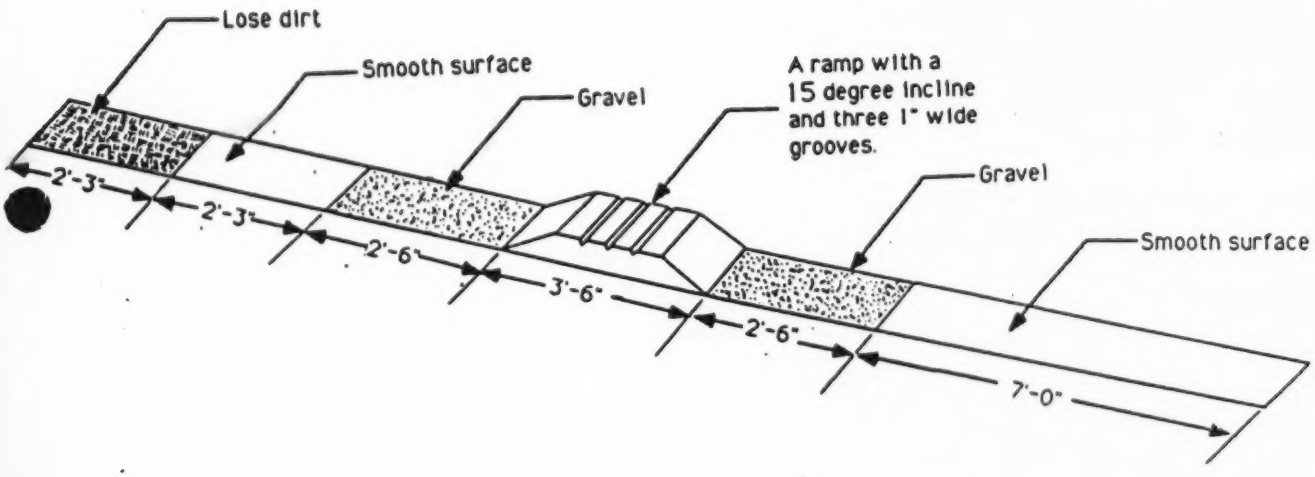
OPTIONAL:

- A computer and monitor	15,000/day
- CAD software package	5,000/day
- Spreadsheet software package	5,000/day

Bill of Materials SH #4

Date	Part or Equipment	Quantity	Price/item	Total Cost

Sample Lunar Rover Test Track



Activity Analysis

1. What impact has the lunar rover made on space exploration?

_____

_____

_____

2. When designing a lunar rover, what are some key factors that must be taken into consideration?

_____

_____

_____

PROPULSION PROBLEM SOLVING ACTIVITY

(Compressed Air Propulsion System)

Introduction:

The National Astronautics and Space Administration is constantly trying to develop a system which will deliver a payload into orbit. The safe return of the delivery system is an important part of their mission.

This Technology Education Activity will allow the students to assume the role of a NASA engineer.

Materials and Supplies:

Provide each group of two or three students the following:

- 2 liter plastic soda bottle
- Plastic trash bag
- String
- Masking tape
- Payload (e.g., 35 mm. film capsule, raw egg)
- Launch pad (DR. #1)
- Tire pump

Problem Statement:

As chief engineer for NASA, you are responsible for developing a delivery system which will send a payload into orbit and return again safely.

Activity Procedures:

1. Obtain the materials needed to complete the activity.

2. Using plastic trash bags, string, and masking tape, design a system which will launch a payload as high as possible and a recovery system that will return it safely to the ground.

3. Once your group feels they have a launch and recovery system that will work, practice launching your design.

4. Test your launch vehicle and recovery system.
   A. Open the hinges on the launching device (DR.#1).
   B. Fill the launch vehicle 1/4 full of water.
   C. Place your finger over the end of the bottle, so the water does not spill and place it on the #3 chemistry stopper.
   D. Once the bottle is in place, fold the hinges so they hold the bottle in place.

E. Next, carefully position the trigger latch so it holds the hinges closed. (Safety Note: Be sure the trigger latch is secure before you begin adding pressure to the bottle.) (NOTE: There should be two pieces of string tied to the launch latch. One should be approximately 10-15 feet long (used to self-release the vehicle) and the other should be about 2 feet long. The two foot piece of string should be tied to the trigger and attached to the launch device. This is done to prevent the trigger from coming back and hitting the person who sets off the vehicle.)

F. Once the vehicle is safely in place and secure, attach a tire pump to the truck tire valve stem located on the launching device. Then, pump the air into the bottle. Even though the bottle will hold upwards of 140 pounds of pressure, for safety **do not** put more than 100 pounds in the bottle.

G. After the vehicle has been pressurized, have one group take the string which is attached to the trigger latch and move the end of the string (should be approximately 10-15 ft.). Be sure everybody is back approximately 20-30 feet from the launching device. When all are standing clear, start a count down from 10 to 0 and launch the vehicle.

H. How did the launch vehicle perform?

I. Did the recovery system safely return the payload to earth? If not, describe what modifications are needed to correct the problem.

5. If necessary, make modifications.

6. Continue to refine and test your launch vehicle and recovery system until it can perform three consecutive flights safely.

Activity Analysis:

Based on the experience gained by conducting this activity:

1. Discuss the modifications that were made to improve the vehicle's weight.

_____

_____

2. Discuss how the use of compressed air causes the launch vehicle to lift.

_____

_____

3. Describe the recovery system used to bring the payload safely to earth.

_____

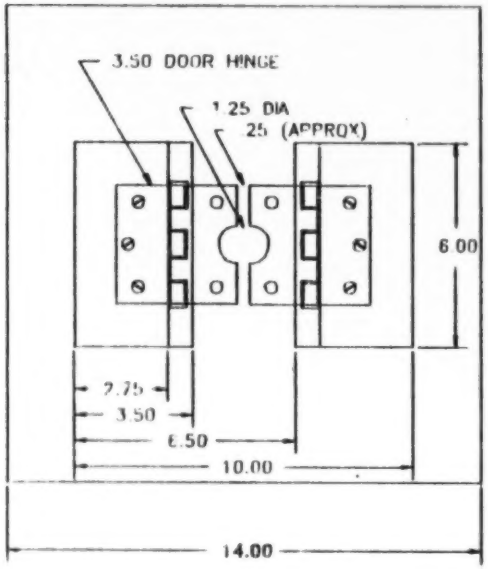
_____

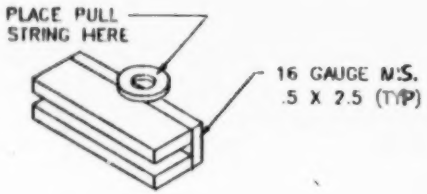
4. Did the recovery system work? _____ If no, what modifications were made to improve the recovery system's performance?

_____

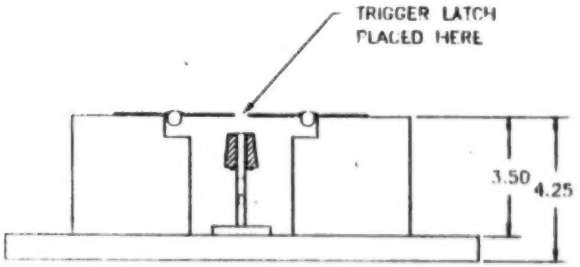
_____

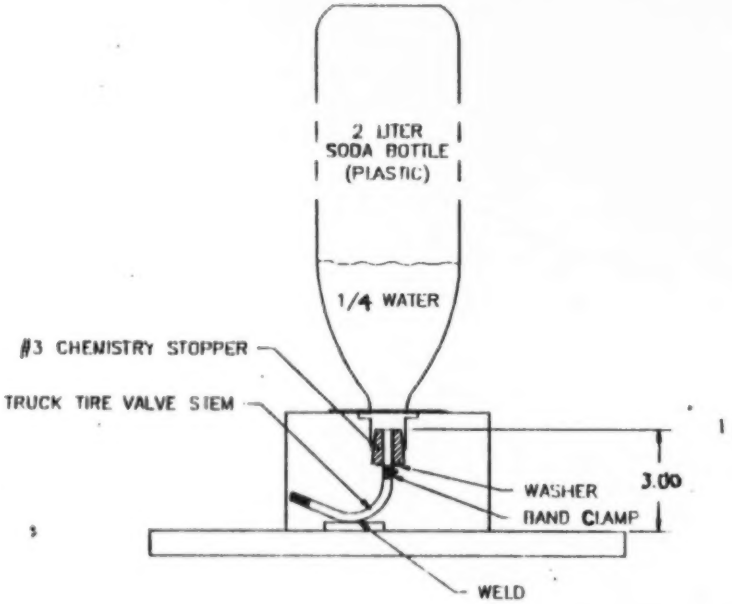
DR #1





TRIGGER LATCH





23-S

PNEUMATIC PROPULSION SYSTEM